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GENERAL VEHICLE TEST INSTRUMENTATION EVALUATION

Prepared by
Transportation Systems Center

MARCH 1977

FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Technology Development and Deployment
Office of Rail Technology
Washington DC 20590

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16. Abstract

A General Vehicle Test System (GVTS) has been developed by the Transportation Systems Center, Cambridge, Massachusetts to facilitate rail transit vehicle testing at the Transportation Test Center, Pueblo, Colorado. This system was designed to be responsive to requirements specified in the publication GENERAL VEHICLE TEST PLAN (GVTP) for URBAN RAIL TRANSIT CARS, report number UMTA-MA-06-0025-75-14. This report presents the results of the evaluation tests performed on the GVTS instrumentation in May, 1975 under actual rail transit operating conditions. Parameters evaluated include vehicle current, voltage, acceleration/vibration, pressure, temperature, displacement, and strain. The GVTS as tested provides 37 of the 48 required Standard Outputs described in the GVTP. Additional equipment and/or development is required to provide full coverage of the required 48 outputs.

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PREFACE

Under the sponsorship of the Office of Rail Technology of the Urban Mass Transportation Administration, Office of Technology Development and Deployment, the Transportation Systems Center (TSC) provides technical support for improving urban rail transportation systems. To facilitate rail vehicle testing at the Transportation Test Center (TTC) in Pueblo, Colorado, the Urban Rail Supporting Technology Program at TSC has developed a General Vehicle Test System (GVTS). This system includes instrumentation, digital data acquisition and processing equipment and certain special purpose measurement systems and was designed to be responsive to requirements specified in the General Vehicle Test Plan (GVTP) for Urban Rail Transit Cars, document number UMTA-MA-06-0025-14, September 1975.

This report presents the results of evaluation tests performed on the GVTS instrumentation at the TTC during May, 1975. The primary objective of this series was to determine the operating characteristics of the instrumentation under actual rail vehicle test conditions. Sufficient data was collected and analyzed to permit evaluation of this instrumentation.

The performance of this test series required the cooperative efforts of many individuals. The TSC test crew, under the direction of George Neat, included the author and Thomas Hayes. The TSC resident at the TTC, Robert Brush, coordinated the test center support personnel. Ray Figueroa and Frank Raia from the New York City Transit Authority provided exceptional on-site assistance with the R42 test vehicle.

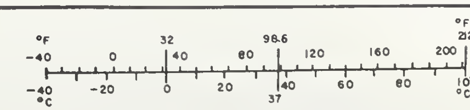
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

1.1 BACKGROUND

The Office of Rail Technology of the Urban Mass Transportation Administration (UMTA) Office of Technology Development and Deployment is conducting programs directed towards the improvement of urban rail transportation systems. These research and development programs will result in improved prototype vehicle and component designs, improved ways and structures, and improved structural components.

The Transportation Systems Center (TSC) is System Manager for the necessary technical support in these developmental areas. The UMTA-sponsored Urban Rail Supporting Technology (URST) Program at TSC has implemented a test program which has included tests on the New York City Transit Authority and the Massachusetts Bay Transportation Authority as well as on the Rail Transit Test Track at the Transportation Test Center (TTC) in Pueblo, Colorado.

A General Vehicle Test System (GVTS) has been developed by the TSC to facilitate vehicle testing at the TTC. This system was designed to be responsive to requirements specified in the publication General Vehicle Test Plan (GVTP) for Urban Rail Transit Cars, report number UMTA-MA-06-0025-75-14 (formerly TSC GSP-064). The purpose of this referenced document is to provide a standardized framework for the planning, execution, data analysis, and reporting of urban rail vehicle tests. To accomplish the required standardization, Standard Output specifications are listed and defined in the GVTP. These output lists describe the required operating

characteristics of the instrumentation to be utilized to make the measurements and the required signal processing characteristics for derived outputs. Parameters to be measured include electrical current, voltage, acceleration/vibration, pressure, temperature, displacement, and strain.

1.2 PURPOSE

This report presents the results of evaluation tests carried out on the General Vehicle Test System (GVTS) at the Transportation Test Center (TTC), Pueblo, Colorado in May 1975. The GVTS is an integrated instrumentation system consisting of transducers, signal conditioners, signal filters, interface and control electronics, a data acquisition system, signal monitoring and output devices, and all related hardware and software. For purposes of design and development, the GVTS is divided into three parts,

- Part 1: The instrumentation system up to and including the signal filters and associated hardware.
- Part 2: The digital data acquisition system with associated software, and
- Part 3: Special purpose measurement systems such as noise, radio frequency interference, spin/slide, adhesion, and dynamic shake.

The objective of this test series was to evaluate the performance of the instrumentation system under actual rail transit operating conditions. Sufficient data was collected and analyzed to permit evaluation of the instrumentation system. The evaluation of the digital data acquisition system and the special purpose measurement systems will comprise future test programs.

A companion document, General Vehicle Test Instrumentation Manual to be published, March 1977 describes each of the instrumentation systems in detail. This manual includes the following information:

A) System Use

B) Special Handling Requirements

C) Theory of Operation

D) Functional Wire List

E) Shield/Ground Technique

F) Mode Card Setup

G) Vehicle Mounting

H) Calibration

The equipment evaluated herein for General Vehicle Testing is complemented by a second system developed under contract to Boeing Vertol Co. for use on the State-of-the-Art Car (SOAC) test program. The SOAC instrumentation system includes analog magnetic tape recorders and is described in Volume VI of the SOAC test report.*

1.3 APPROACH

Section 2.0 of this document describes the test series facilities, instrumentation overview, methodology, documentation, and status. Test results are presented in Section 3.0. Section 4.0 compares the GVTS evaluated during this test series to the requirements specified in the GVTP. The instrumentation common to all of

*State-of-the-Art Car Engineering Tests at Department of Transportation High Speed Ground Test Center, Final Report, Volume VI: SOAC Instrumentation System, Report number UMTA-MA-06-0025-76-6, National Technical Information Service, Springfield, Virginia 22161, Document Number PB-244 752

the tests in this series is described in Appendix A, while subsequent appendices describe each individual test including data samples.

2. TEST DESCRIPTION

2.1 FACILITIES

The test series was performed at the Transportation Test Center (TTC) in Pueblo, Colorado. The 9.1-mile Rapid Transit Test Track (RTTT) described in Figures 2-1 and 2-2 was used for all tests, and equipment installation and maintenance was done in the adjacent Transit Maintenance Building (TMB). The test vehicles were a married pair of New York City Transit Authority (NYCTA) R42 cars. These vehicles were leased from the NYCTA and were used on various TTC test programs since 1971. The vehicles are shown in Figure 2-3. The prime power for the vehicle in this test series was supplied by the TTC diesel locomotive, DOT-001, and two auxiliary generators. The 600-volt direct current was distributed via a third rail.

2.2 INSTRUMENTATION/METHODOLOGY

A block diagram of the GVTS is shown in Figure 2-4. The test categories are listed in the left column, and the component classifications and locations are listed along the base. Seven basic categories are listed. These include:

a) Reference Data

b) Current

c) Voltage

d) Acceleration/Vibration

e) Pressure

f) Temperature

g) Structures

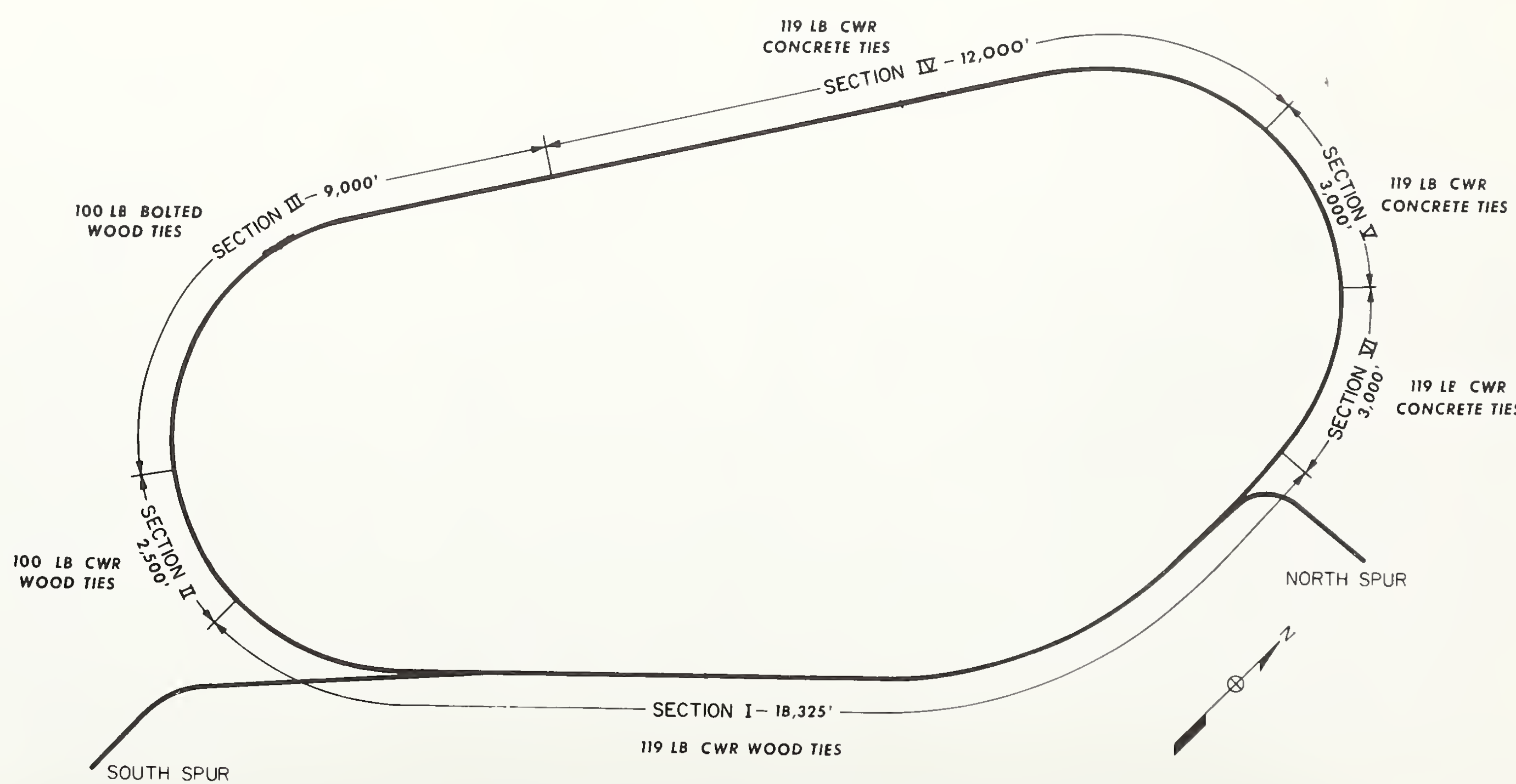


FIGURE 2-1. UMTA RAPID TRANSIT TEST TRACK DIAGRAM

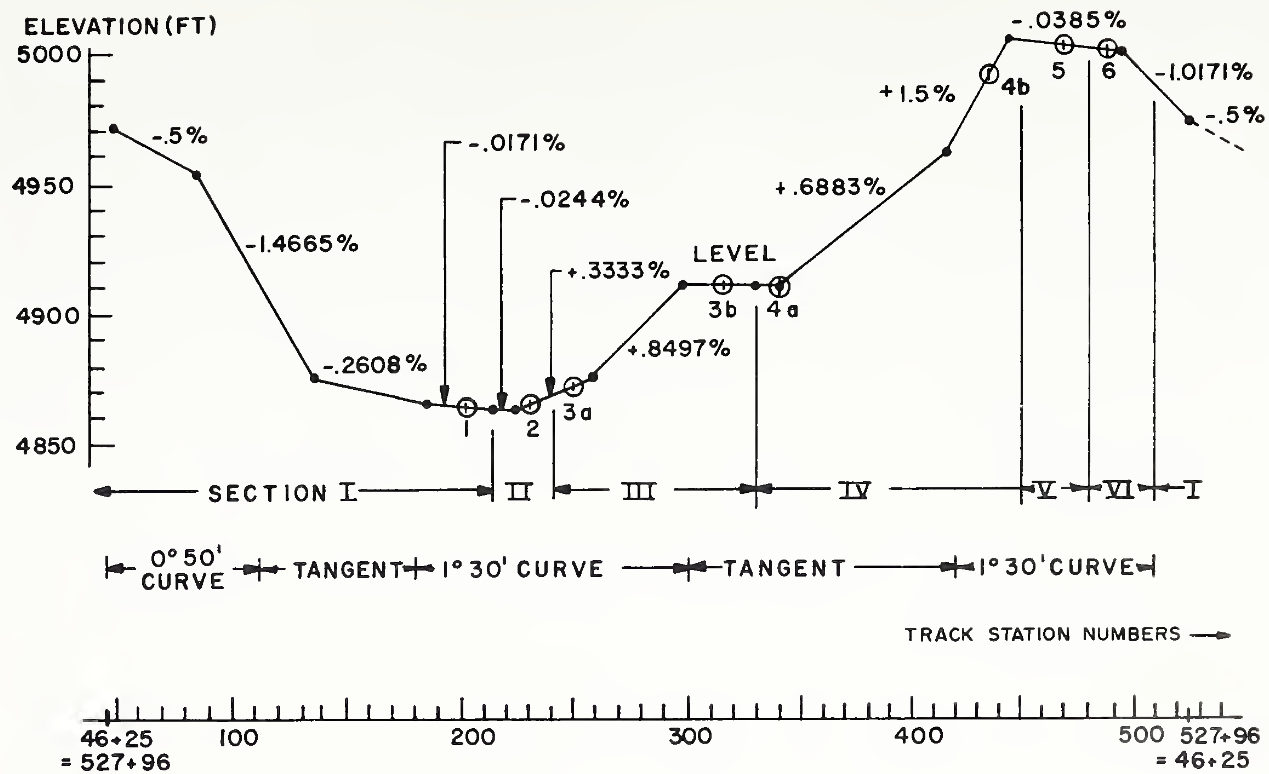


FIGURE 2-2. GRADE OF TEST TRACK

FIGURE 2-3. NEW YORK CITY TRANSIT AUTHORITY R42 CARS AND TTC DOT 001 DIESEL LOCOMOTIVE

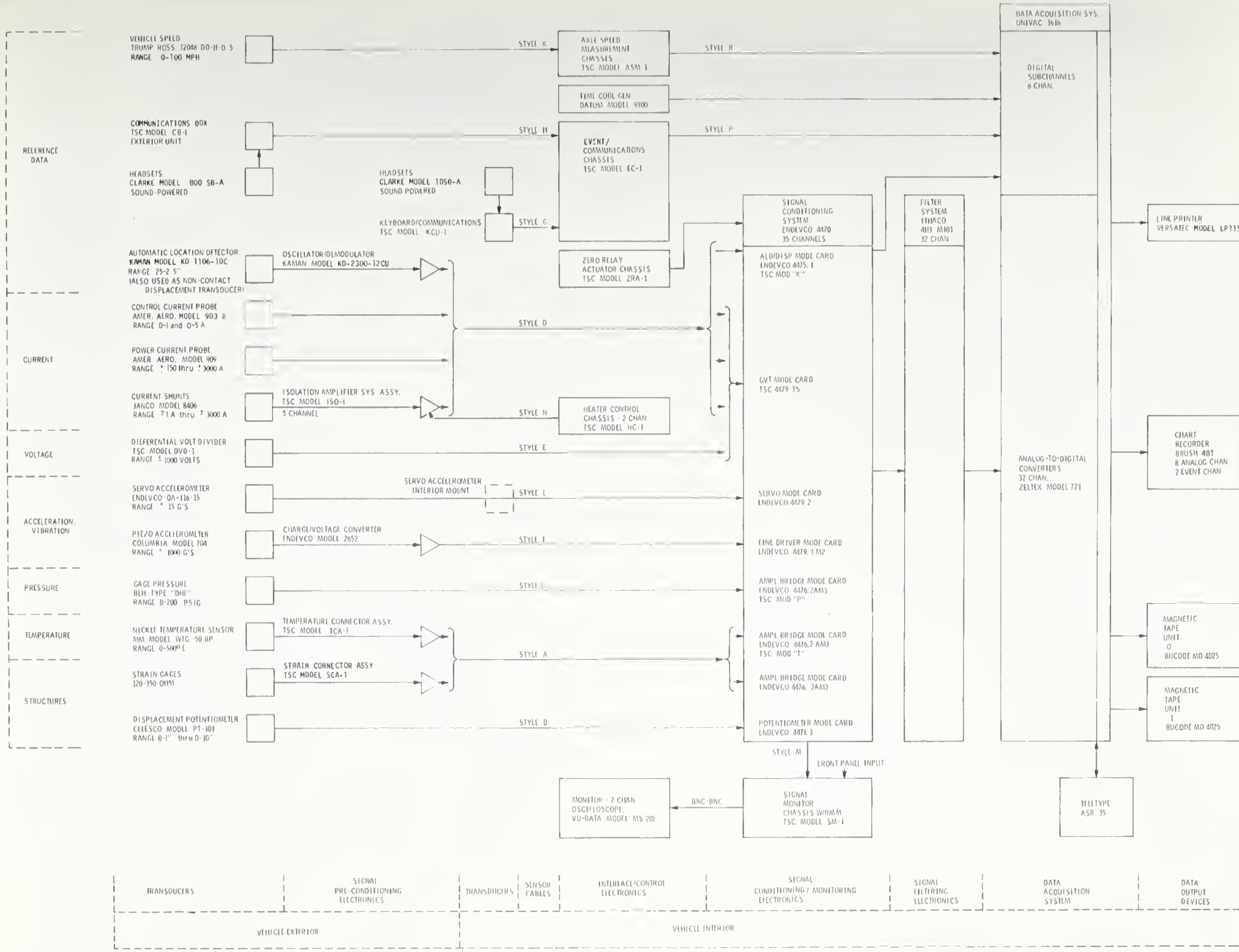


FIGURE 2-4. GENERAL VEHICLE TEST SYSTEM BLOCK DIAGRAM

This test series was designed to evaluate candidate instrumentation systems for performing measurements in the preceeding seven areas. Representative samples of all types of GVTS equipment* were installed on the vehicle in specialized configurations. The test setups were designed to provide the following information.

1) Redundant Measurement Agreement. In many cases, two identical instrument systems were installed to measure the same vehicle parameter. Agreement of the two signals provided an indication of system performance.

2) Noise Pickup. Wherever possible, "dummy" sensors were fabricated to simulate actual sensors with a steady state output value. Any dynamic system output would indicate an electrical or mechanical noise with degrading effects on actual sensors.

3) Zero Signal Drifts. Wherever possible, the input to a given sensor was reduced to zero (current and voltage to a motor with the vehicle stopped, for example). By periodically analyzing this signal, conclusions can be drawn concerning the zero stability of each instrumentation subsystem.

The signal conditioning, filtering, monitoring, and control equipment was housed in a shock-mounted, three-bay, electronic rack shown in Figure 2-5. A layout of the rack equipment is shown in Figure 2-6. Sensors were installed both inside and outside of the

*The digital data acquisition system is shown in the block diagram but for this test series, an analog magnetic tape recorder was used.

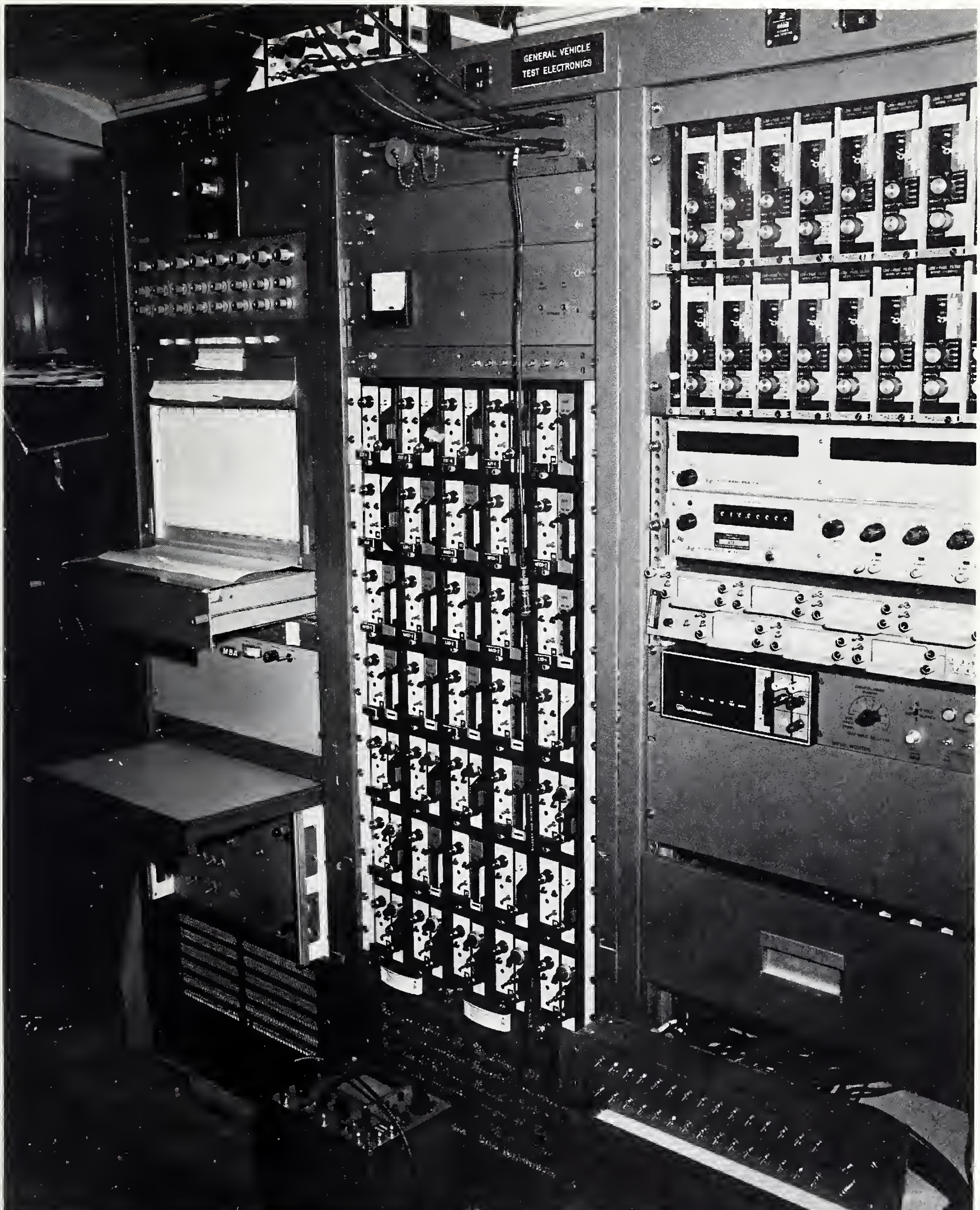


FIGURE 2-5. VEHICLE MOUNTED EQUIPMENT RACK

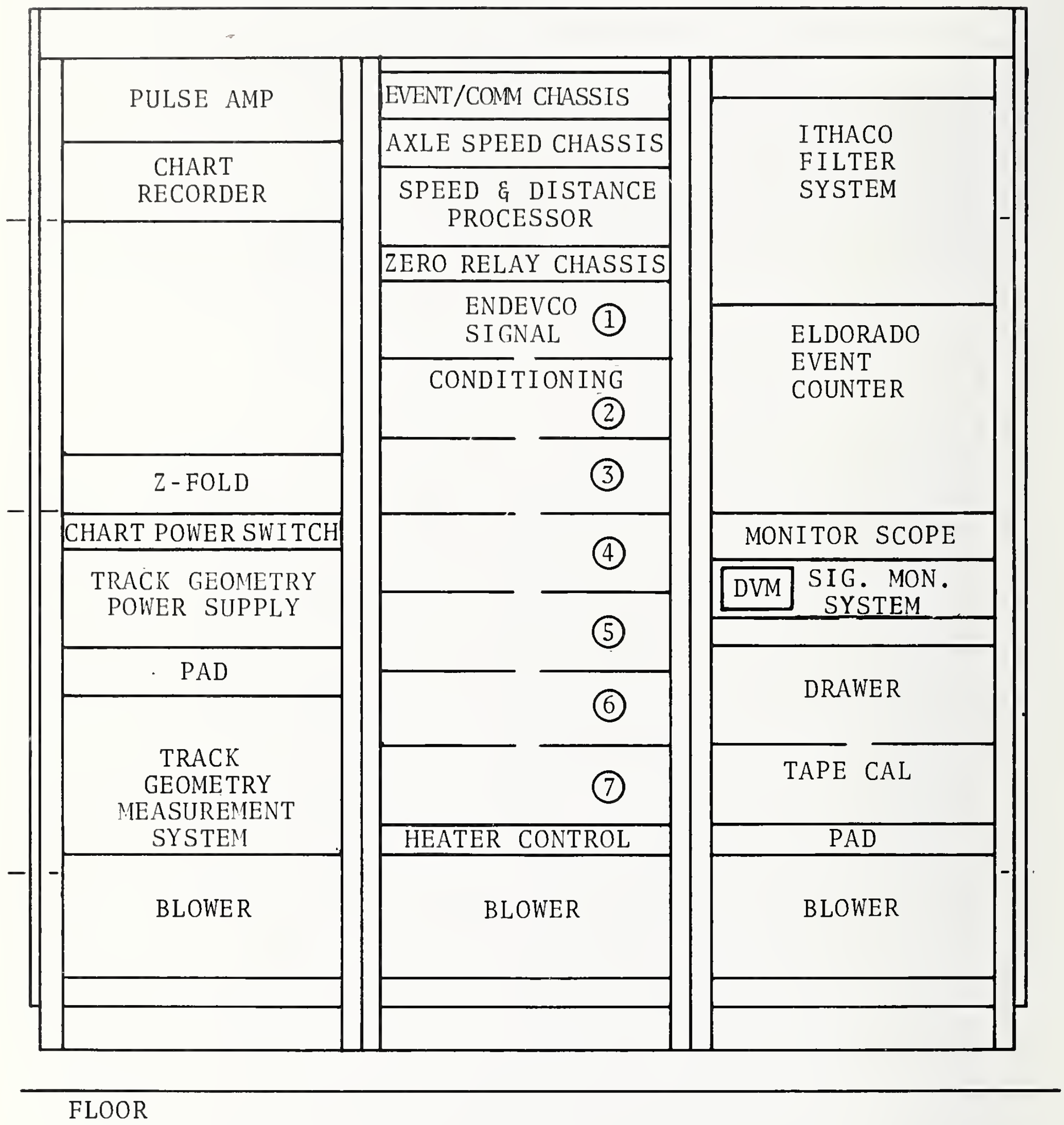


FIGURE 2-6. LAYOUT OF EQUIPMENT RACK

vehicle as required with standardized 60-foot cables connected to the rear of the signal conditioning chassis. The shock-mounted tape recorder with power supply was located in the vehicle floor in front of the equipment rack.

Forty-two test runs were performed to complete 11 tests with analog data recorded on the 14-channel FM magnetic tape recorder. Real-time evaluation and debugging of the sensor systems was accomplished by selective monitoring of signals on an oscilloscope and 8-channel chart recorder. Post test processing included the differential summation of redundant low frequency data signals, frequency spectral analyses, time expanded chart recordings, and manual dc-signal-level tabulations. The common equipment used during the test series is described in Appendix A with details of each sensor subsystem test given in subsequent appendices.

In addition to the test evaluations specified in the test plan, data concerning other test instrumentation was recorded. This data concerns the magnetic tape recorder performances, onboard power supplies, nearby radio communication effects on data, and the equipment rack vibration isolation characteristics. These items are discussed in Appendix F.

2.3 TEST DOCUMENTATION/STATUS

To facilitate reporting of the test data and correlation with previous tests, a standardized numbering system was used. Each scheduled test was identified by a test set number. The applicable numbers are listed and described in Figure 2-7.

Test Category	Test Set No.	Test Title
Reference Data Systems	R42-I-5103-TT	Communications Evaluation
	R42-I-5107-TT	Rotary Pulse Generator (RPG) Friction Mount Evaluation
	R42-I-5108-TT	Automatic Location Detector Eval.
	R42-I-5109-TT	Vehicle Speed Measurement vs. Speed, Curved or Tangent Track, Wet/Dry Rails, Vehicle Direction, Comparision with Accelerometer Output.
Current/Voltage Systems	R42-I-5201-TT	Current Shunt/Voltage Divider Eval.
	R42-I-5202-TT	Current Probe Evaluation
Pressure, Temperature, Strain, Displacement Systems	R42-I-5301-TT	Pressure, Temperature and Strain Systems Evaluation
	R42-I-5302-TT	Displacement Systems Evaluation
Acceleration/Vibration	R42-I-1110-TT	Acceleration/Vibration
Miscellaneous	R42-I-0101-TT	Zero Signal Shift vs Cable Position
	R42-I-2106-TT	Carbody Voltage Variations
	R42-I-5105-TT	Magnetic Fixture Evaluation
	R42-I-0102-TT	Thermal Environment Three Bay Rack
	R42-I-5104-TT	Vehicle Shakedown Run

Numbering System Explanation

Test Set No. R42-I-5XXX-TT

Vehicle

Rapid Rail Test Track

Instrumentation Development

Operating Procedure
5 ≈ Sample Service
2 ≈ Acceleration
1 ≈ Steady Speed
0 ≈ Stationary Vehicle

Note: The last three digits of the operating procedure correspond to the series number assigned in the test plan.

FIGURE 2-7. TEST SUMMARY, TEST SERIES 18, MAY, 1975

In addition, each vehicle operation that resulted in the acquisition of data was assigned a run number of the form 200/1. The first three digits correspond to the instrumentation setup while the last digit is the sequential vehicle operation number established prior to each run.

Of 14 tests planned, 11 were carried out. Two, R42-I-5107-TT and R42-I-5109-TT, were deleted because of a failure in in the rotary pulse generator (RPG) vehicle speed system. The system exhibited erratic speed indications and signal dropout. A post-test TSC laboratory evaluation indicated two distinct problems. A special purpose connector had an intermittent short and an opto-isolator had been incorrectly wired with resultant signal oscillation under certain test conditions. A vehicle speed indication was provided by a handheld police-type radar gun operated by the forward observer. Vehicle speed was periodically recorded on the tape voice track, chart recorder notes, and log book.

A third test, R42-I-0102-TT, was considered low priority and was cancelled to avoid extending the scheduled test period.

3. TEST RESULTS

With the exception of the vehicle speed system, all GVT sensor systems functioned properly during the test series. The results of the tests are summarized in these paragraphs with the experimental system accuracy figures listed where applicable. A sample of analyzed data in the form of a chart record and frequency spectra is shown in the current shunt section for reference. The reader is referred to the appendices for similar data samples from tests of the other sensor systems.

The test results for all tests except the reference data and acceleration measurement systems were derived from simulated sample service runs around the complete loop. The approximate time length of these runs was 28 minutes.

3.1 REFERENCE DATA SYSTEMS

a. Communications

The sound-powered communications system provided adequate fidelity and ease of operation in the conduct of the tests. The use of eight outlet boxes provided communications to all necessary areas of the test vehicle. The tape recording of this audio signal facilitated the data analysis.

b. Automatic Location Detector (ALD)

Initial problems with false indications were eliminated by reducing the allowable probe/target spacing to two inches. Remaining tests of the system indicated satisfactory performance with no false signals recorded.

Use of the ALD as a precision distance measurement device appears possible.

3.2 CURRENT MEASUREMENT SYSTEMS

a. Current Shunt with Isolation Amplifier

The current shunt sensors were installed in the motor field circuit where the voltage potential with respect to ground was 600 Volts dc. The low level shunt signal was isolated from this common mode voltage in an isolation amplifier. The resulting ground referenced signal was then conditioned and recorded. Performance of the system was satisfactory. The full scale (FS) range was 500 amperes.

Zero Signal Drift . . . . 0.2% FS MAX

To reduce the effects of temperature induced zero signal drifts, the isolation amplifiers were temperature controlled. After a specified warm-up of 2 to 4 hours, depending on ambient temperature, the drifts were less than the above figure.

Noise . . . . 0.1% FS MAX

Figure 3-1 is a chart record of the beginning of run 200/6, a sample service run to test the current shunt and voltage measurement systems. The field current is shown on channel 2 while noise data is shown on channels 1 and 3. As described in Appendix C, the isolation amplifier input of channel 1 had both leads connected to ground but a malfunction of another unit

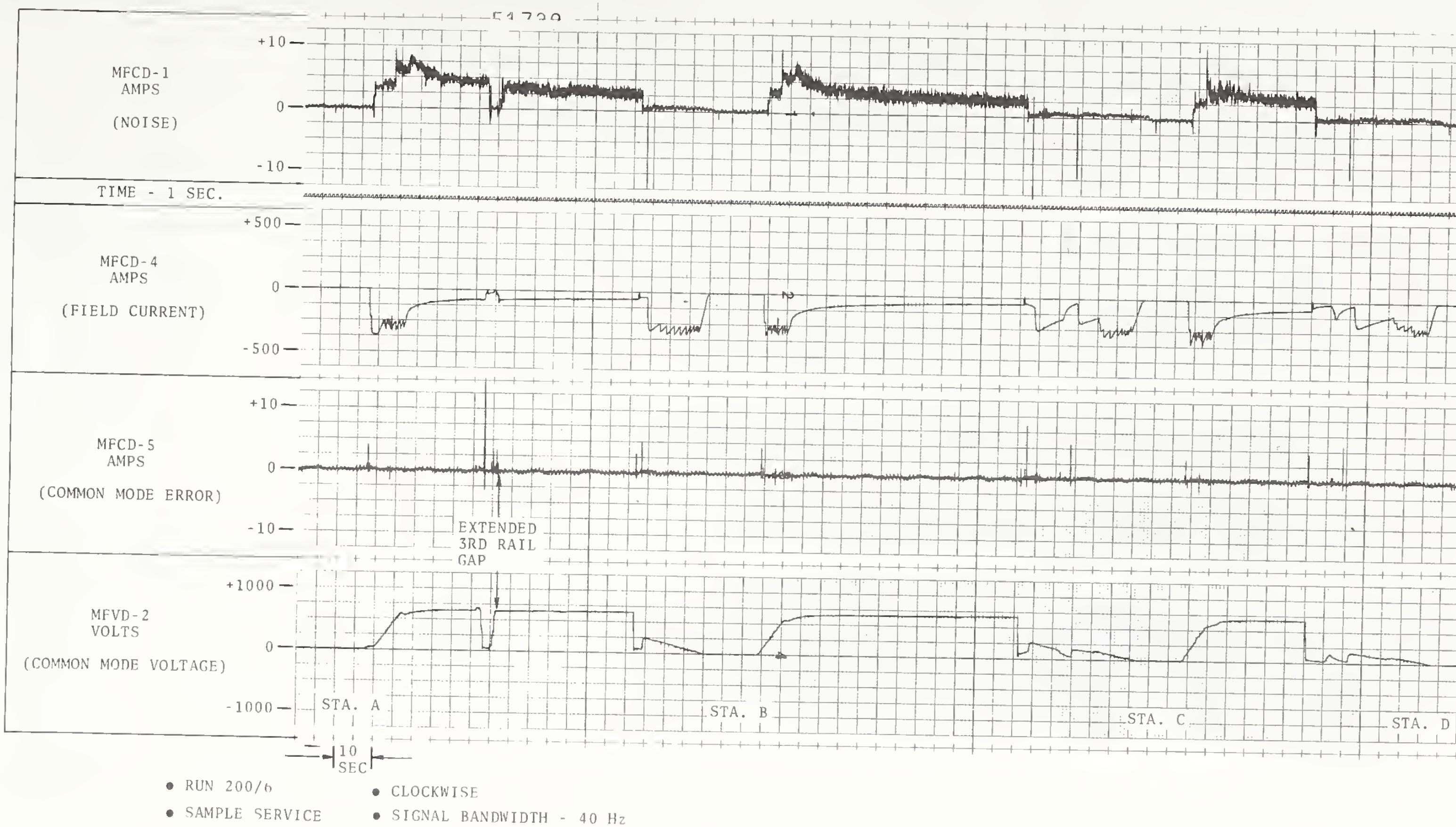


FIGURE 3-1. CURRENT SHUNT AND VOLTAGE NOISE SIGNAL CHART RECORD

did not allow the 20-foot cable to be properly installed for this test. Output signal shifts up to 1.5 percent FS on this zero signal channel are believed to be caused by pickup in the coiled input cable. On future tests, the cable would be properly installed and pickup would be reduced. These output shifts are not evident on the MFCD-5 signal which had both input leads attached to the 600-vdc line. This cable was properly installed.

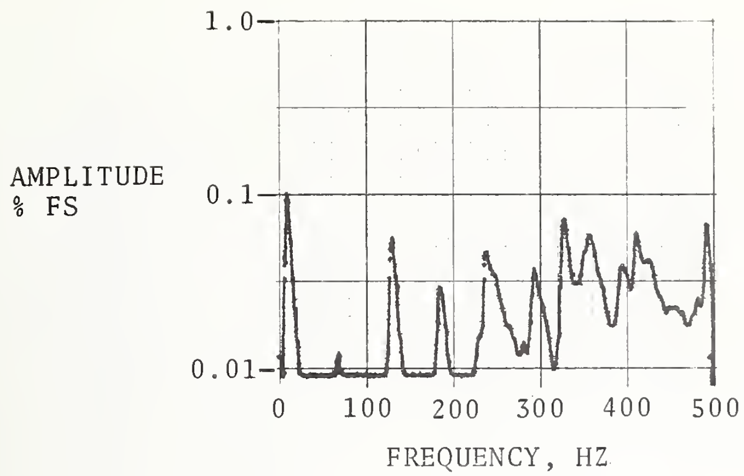
Frequency spectra of the MFCD-1 signal and the appropriate tape channel noise are given in Figure 3-2. It is conservatively stated that noise pickup is less than 0.1 percent FS on these shunt signals.

Common Mode Rejection Ratio

MFCD-5 had both isolation amplifier leads connected to the same shunt terminal in the field circuit. On the low frequency chart record in Figure 3-1, it is seen that as the field voltage changes, short duration transients were evident on the shunt signal. These transients do not significantly degrade the system performance.

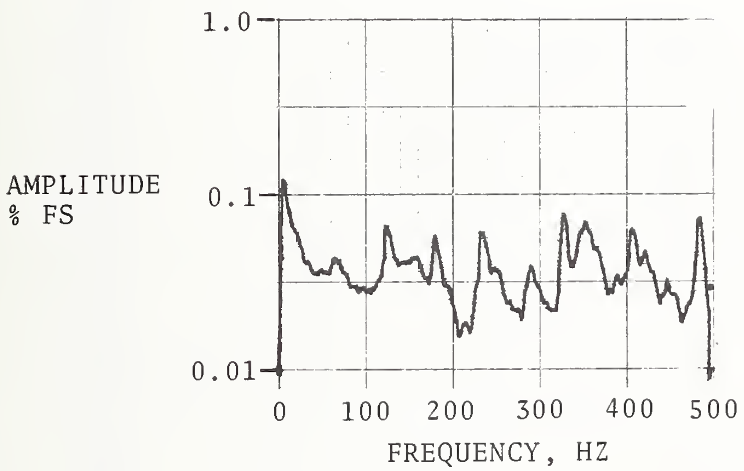
Redundant Data Comparison . . . . 0.5 FS MAX.

Figure 3-3 displays three redundant motor field current signals and their electrical summation signal. Ideal systems would result in a zero summation signal. The added noise on the lower summation was caused by a



TAPE NOISE (TN)

FIGURE C-19(a)



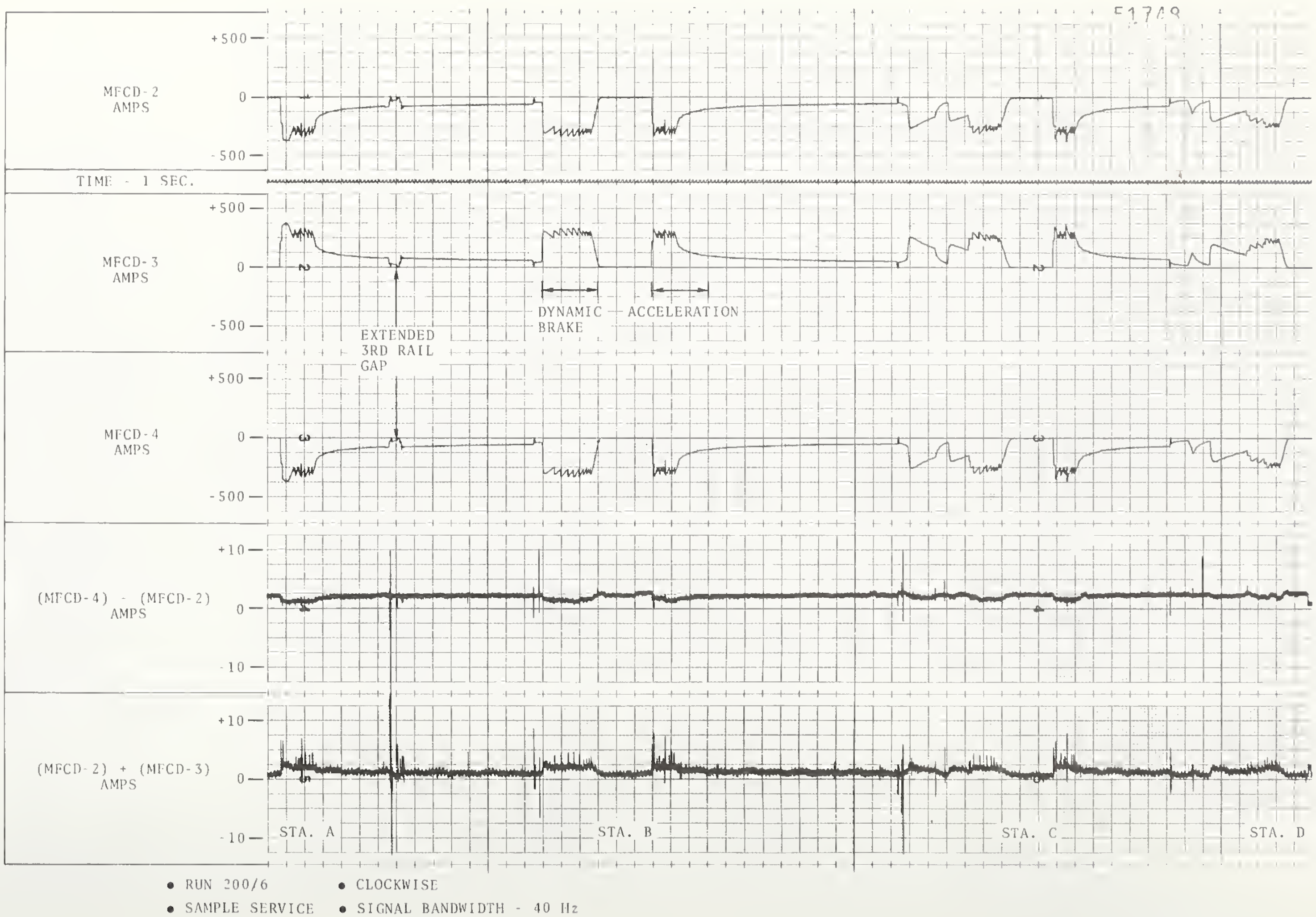
SIGNAL NOISE (SN)

FIGURE C-19(b)

- RUN 200/6
- CLOCKWISE
- 40 MPH CONSTANT SPEED
- 500 Hz

NOTE: 1.0% FS OF THE TAPE RECORDER OUTPUT CORRESPONDS TO A 10 MV PEAK DISCRETE FREQUENCY SINE WAVE USED TO CALIBRATE THE SPECTRUM ANALYZER.

FIGURE 3-2. CURRENT SHUNT NOISE SIGNAL FREQUENCY SPECTRA



- RUN 200/6
- CLOCKWISE
- SAMPLE SERVICE
- SIGNAL BANDWIDTH - 40 Hz

FIGURE 3-3. CURRENT SHUNT REDUNDANT SIGNAL CHART RECORD

tape head misalignment that induced a slight time shift between the signals.

b. Current Probe

Laboratory evaluations of the current probes indicated that the vehicle installation was extremely critical. The magnetic fields from nearby current carrying conductors and motors and magnetic material all degrade sensor performance. During this test, the probes were mounted mid car and also on the trucks where a more severe magnetic environment existed. Shunts were used as reference signals when comparing data. The data indicates that truck mounted probes were unsatisfactory while errors up to 5 percent FS occurred on the mid car probe signals.

Future use of these current probes will require the installation of a jumper cable in the appropriate circuit. This cable would be routed away from all other conductors and magnetic field producing equipment. The probe would then be clamped to this jumper in the same orientation as it was calibrated. With these precautions, it is estimated that data with accuracies in the order of 2 to 3 percent of the FS range could be achieved.

Advantages of the current probes include a high frequency response (10 kHz versus 3 kHz for the current shunt system) and insensitivity to common mode voltages.

Zero Signal Drift . . . . 1.1% FS Max.

The maximum zero drift occurred on a mid-car probe.

The average drift of the four probes was 0.6 percent FS Max.

Redundant Data Comparison . . . . Mid car 5% FS Max.
Truck 15% FS Max.

Maximum summation signals from mid-car probes and current shunts ranged from 2.5 to 5 percent FS Maximum truck probe summations exceeded 10 percent FS.

3.3 VOLTAGE MEASUREMENT SYSTEM

Voltage sensors were installed in the motor field and line input circuits. Data analysis indicated that performance of the devices was satisfactory. No special installation techniques were required. The full scale (FS) range was 1000 volts.

Zero Signal Drift . . . . 0.1% FS Max.

Three of five tested sensors exhibited negligible drift.

Noise . . . . 0.1% FS Max.

The differences in tape channel noise and sensor system noise frequency spectra were only significant at 60 Hz. A noise level of 0.90% FS occurred at this frequency.

Redundant Data Comparison . . . . 0.5% FS Max.

Three sensors were connected from ground across the motor field circuit such that their summation should equal zero. Manual precision voltmeter measurements

of each signal and algebraic summation yielded the above result.

3.4 PRESSURE MEASUREMENT SYSTEM

Brake cylinder air pressure was measured with two 200 psig range strain gage transducers. Performance of the pressure system was satisfactory.

Noise . . . . 0.1% FS Max.

Frequency spectra indicated a low noise level with no dominant frequency components.

Redundant Data Comparison . . . . 0.25% FS Max.

An electrical summation of the two redundant signals indicated a slightly higher scale factor on one system.

3.5 TEMPERATURE MEASUREMENT SYSTEM

Three temperature measurements were made with a 500°F full scale range. The system utilized bondable resistance temperature gages. Performance of the system was satisfactory.

Zero Signal Drift . . . . 0.2% FS Max.

One of the temperature channels simulated a constant temperature using fixed, stable resistors. Drift of this channel during the test run was equivalent to 1°F.

Noise . . . . 0.1% FS

Frequency spectra of the temperature signals indicated a low noise level with no dominant frequency components.

Redundant Data Comparison . . . . 0.25% FS Max.

Two of the sensors were mounted close together on a resistor grid heat shield. These signals displayed close agreement.

3.6 STRAIN MEASUREMENT SYSTEM

One four-arm strain gage bridge was installed on the vehicle and another strain signal simulated by a commercial strain gage calibrator. Performance of the system was satisfactory. The full scale (FS) range was 250 micro-inches per inch (250 μ in/in).

Zero Signal Drift . . . . 0.1% FS

The calibrator signal was used as a reference and exhibited low drift.

Noise . . . . 0.1% FS

Frequency spectra of the calibrator signal indicated a low noise level. Low magnitude frequency peaks were noted at 60 and 180 Hz.

3.7 DISPLACEMENT MEASUREMENT SYSTEMS

a. Potentiometer Displacement Sensors

The spring loaded potentiometers provide an output signal proportional to the displacement of an extension cable. The ranges of the instruments are 1, 3, 5, and 10 inches. Seven sensors were installed on the test vehicle with satisfactory results. Certain precautions are necessary when installing the sensors to minimize the extension

cable vulnerability to track debris. To extend the useful life of the sensors, the extension cables should only be connected during actual testing.

Zero Signal Drift . . . . 0.1% FS Max.

Two one-inch range sensors were mounted on the carbody with their extension cables hard mounted. Maximum drift of these zero signal configuration sensors was low.

Noise . . . . 0.1% FS Max.

Noise could be induced by an extension cable vibration or electrical pickup. Frequency spectra indicated a low noise level with no dominant frequency components.

Redundant Data Comparison . . . . 3.0% FS Max.

Two sensors were used to measure the swing link lateral displacement. A close examination of the data indicated that the cable retraction of one sensor was slightly delayed creating a time shift between the two signals. The agreement between signals with the vehicle stationary was better than 1 percent FS.

b. Noncontact Displacement Sensor

One noncontact sensor was installed to measure journal box to truck frame relative motion. A potentiometer sensor also provided the same measurement. Performance of the noncontact device was satisfactory. Experience with the sensor indicated accuracies of 1 percent FS are obtainable.

Noise . . . . 0.1% FS Max.

Frequency spectra of the displacement signal indicated a low noise level. No dominant frequency components were observed.

Redundant Data Comparison . . . . 4% FS Max.

The noncontact probes are inherently nonlinear but adjustments are provided to electrically linearize the system. Testing time constraints did not allow a detailed, accurate calibration. Comparison of this signal with the pot signal indicated that, at large displacements, differences of 4 percent were observed on the summation signal.

3.8 ACCELERATION AND VIBRATION MEASUREMENT SYSTEMS

a. Servo Accelerometers

Carbody acceleration measurements were made with servo accelerometers. Five units were mounted on the car floor and equipment rack along with a zero-g simulator accelerometer. The full scale range was ± 0.5g. Performance of the accelerometer systems was satisfactory but it is recommended that each unit be dynamically calibrated. Both amplitude and phase shift up to 200 Hz should be determined.

Zero Signal Drift. . . . . 0.3% Max.

The recorded simulated zero-g accelerometer signal was monitored during a 60 minute test period. The above drift corresponds to 1.5 milli-g.

Noise . . . . 0.1% FS Max.

Frequency spectra (dc-200 Hz) of the simulated zero-g signal indicated a low noise level. No dominant frequency components were observed.

Redundant Data Comparison . . . . ±1 dB Max.

Frequency spectra of two redundant accelerometer signals agreed within 1 dB from dc to 200 Hz.

b. Piezo Accelerometers

Journal box acceleration measurements were made with piezo accelerometers. Two units were mounted on the journal box along with a zero-g simulator. Performance of the system was satisfactory.

Zero Signal Drift . . . . 0.1% FS Max.

The piezo accelerometer system has a low frequency cut-off of 3 Hz. The zero drift value given above is primarily from the filter system.

Noise . . . . 0.1% FS Max.

Frequency spectra of the zero-g simulated signal indicated a low noise level. No dominant frequency components were observed.

Redundant Data Comparison . . . . ±2 dB Max.

Frequency spectra (0-2000 Hz) were generated for the two journal box vertical accelerometers.

3.9 MISCELLANEOUS TEST RESULTS

a. The zero-signal shift as a function of cable position on high gain systems did not occur at the TTC site. Zero shifts exceeding 1 percent of full scale at TSC labs are believed caused by radio frequency rectification with the cable acting as an antenna.

b. The dc voltage variations induced in the current carrying carbody were less than 35 milli-volts during vehicle acceleration (max. current draw). Potentials of this magnitude are not expected to affect properly grounded equipment.

c. The use of general purpose magnetic sensor fixtures does not appear feasible. Mounting-surface constraints dictate that custom designs must be considered.

d. The magnetic sensor parameter labels that were affixed to the signal conditioning modules performed satisfactorily. Their use facilitated the real time monitoring of specific signals.

e. The analog tape recorder performed satisfactorily during the test. Initial excessive tape noise was reduced by mounting the transport in a shock and vibration fixture with the plane of the tape reels horizontal. The signal-to-noise ratio exceeded 40 dB on most channels. Typical zero signal and gain shifts were 0.2% of full scale during the test runs.

f. The keying of on-board walkie-talkies induced zero shifts on high gain channels. The error effect was a strong function of the distance between the equipment rack and walkie-talkie. Radio transmissions during tests should be minimized and it is recommended that antennas be mounted on the roof of the test vehicle to minimize interference.

g. The vibration characteristics of the three-bay equipment rack are optimized. The vertical and lateral natural frequencies are approximately one octave above suspension system resonant frequencies, but below estimated body bending frequencies.

h. No difference in tape recorder calibration was observed when switching between the 600-vdc, 115-vac inverter power system and an auxiliary diesel generator.

4. CONCLUSIONS

The adequacy of the General Vehicle Test System instrumentation is indicated by comparing the results from this test series with the General Vehicle Test Plan (GVTP)* requirements. The comparison excludes special purpose measurement systems such as:

noise
radio frequency interference (RFI)
dynamic shake
spin and slide
adhesion.

The GVTP requirements are in the form of a "Baseline Test Plan", as shown in the GVTP Table 2-1, and "Standard Outputs", GVTP Appendix B, which defines 48 Standard Outputs. Excluding the special purpose system outputs, 41 outputs were considered in this test comparison to the GVTP. Of these 41 outputs, the requirements for generating 37 outputs were provided by the existing GVTS. The generation of the remaining 4 outputs was not provided for in the GVTS tests and will require some development effort and/or equipment in addition to the existing GVTS. These outputs are:

ACCELERATION, CARBODY ANGULAR .... ACA/A
BRAKE TEMPERATIVE (ROTATING PART) .... BT/A
BRAKE TEMPERATURE (FIXED PART) ...... BT/B
LONGITUDINAL CREEP .... CL/A.

*General Vehicle Test Plan for Urban Rail Transit Cars, UMTA-MA-06-0025-75-14, September, 1975.

Some of the GVTS outputs are derived from others, for example: "ACCELERATION POWER SPECTRAL DENSITY", ASD/A, is derived from "ACCELERATION, CARBODY", AC/A. In such derivations, the data that is processed is sufficiently accurate to allow the derivation to be within specified limits.

All specified parameters of the 37 available GVTS outputs met or exceeded specifications with the following two exceptions:

> EQUIPMENT TEMPERATURES, EQT/A, range is specified at 0 to 1000 °F in the GVTP and was limited to 500° in the GVTS tests.
>
> ACCELERATION, JOURNAL, AJ/A, low frequency response is specified at 0.1 Hz in the GVTP and was 3 Hz in the GVTS tests.

Referring to the Baseline Test Plan, Table 2-1 of the GVTP, a second comparison is made. A complete Baseline Test requires the acquisition of 370 data files (called test records in the GVTP). Each test record reflects a specific vehicle operation and test configuration regarding such factors as instrumentation set, weight, line voltage, speed, etc. Excluding the special purpose measurement systems, 257 test records may be compared. Of these, 255 can be acquired using the existing GVTS equipment. Two DUTY CYCLES - FRICTION BRAKE test records cannot be acquired because of the previously stated limitation of brake temperature measurement capability.

Summarizing, on the basis of qualified existing instrumentation, 77 percent (37 of 48) of the GVTP Standard Outputs can be

acquired from the GVTS as tested. Comparing these available Standard Outputs to Baseline Test requirements, 69% (255 of 370) of the test records can be acquired. With the addition of special purpose measurement system equipment, these percentages would increase to 92% (44 of 48) of the Standard Outputs and 99% (368 to 370) of the Baseline Test records. Special purpose measurements could be covered in future test programs using existing TTC, TSC, or rental equipment when test scheduling time is available. A 100% coverage in both areas will require some developmental effort.

APPENDIX A

EQUIPMENT DESCRIPTION

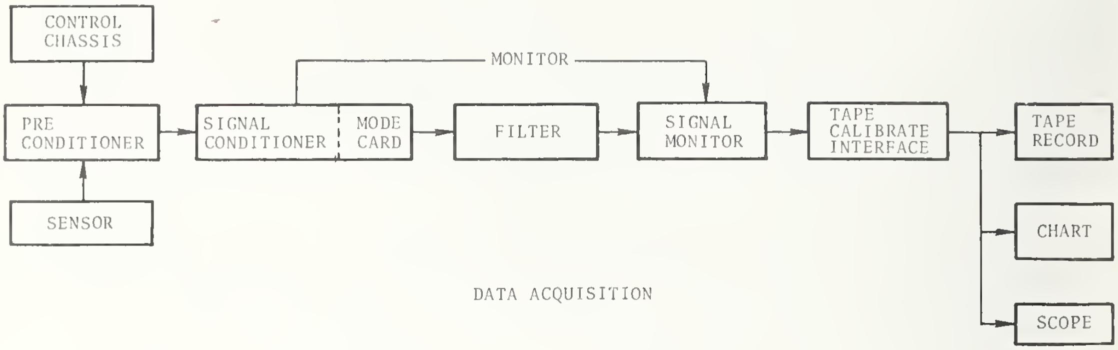
A generalized overview of the sensor, data acquisition, and analysis systems is given in this appendix along with the equipment status. A discussion of the calibration philosophy concludes this appendix.

Generalized block diagrams of the equipment used for data acquisition and reduction are shown in Figure A-1. The individual sensor subsystems differ from the block diagrams as to items of equipment actually used. Equipment items that are applicable to all subsystems are described in the following paragraphs, while remaining equipment items are described with the related sensor subsystem in the other appendices.

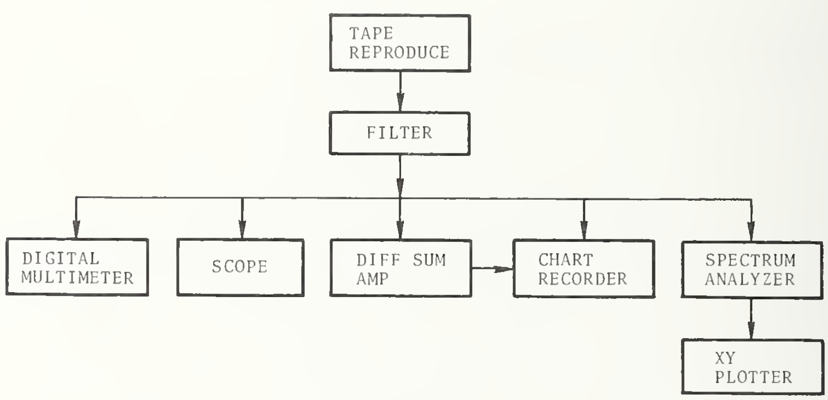
DATA ACQUISITION

Signal Conditioner - Endevco Model 4470

The Endevco Model 4470 signal conditioner consists of 35 modular channels with individual floating power supplies. The shield and grounding for each channel can be optimized independent of any other channel. The isolation between channels exceeds 80 dB. Depending on the sensor subsystem in use, the appropriate plug-in mode card can be inserted. Provisions are generally included for setting scale factor, zero offset, excitation voltage, filter frequency, calibration, and signal monitoring.



DATA ACQUISITION



DATA ANALYSIS

FIGURE A-1. DATA ACQUISITION AND ANALYSIS SYSTEMS GENERALIZED BLOCK DIAGRAMS

Signal Filter - Ithaco Model 4113-M101

The 4113-M101 filter system consists of 32 channels of low-pass, unity-gain filter networks. Each network is 4-pole, Bessel or Butterworth mode with a selectable cut-off frequency from 1 Hz to 1 mHz. Channel isolation exceeds 80 dB.

Signal Monitor System - TSC Model SM-1

Each signal conditioner channel features a front panel monitor toggle switch. Depressing this switch causes the output signal of that channel to be connected to a terminal strip on the rear of the 4470 chassis. To maintain the isolation between channels and allow this monitor signal to be viewed on equipment having a ground referenced input, a buffer amplifier is required. The signal monitor system provides the necessary buffering so that the output of any one of the 35 unfiltered signals may be displayed. The signal is also connected with a digital multimeter that is housed in the SM-1 chassis and is primarily used during system calibration.

An added feature of this chassis is its 14-channel capacity. The magnetic tape recorder used to collect the test data provided single-ended inputs with the signal low common to all channels. Directly connecting the recorder to the filter outputs would obviate any prior channel isolation and place difficult constraints on the signal shield/ground system. To maintain channel isolation and hook-up flexibility, each signal channel was first buffered in the SM-1. The channel isolation in the SM-1 exceeds 80 dB and system integrity is maintained.

During the GVTS testing, three channels of the SM-1 were used in a monitor mode with up to 11 channels serving as buffers for the tape recorder.

Tape Calibrate/Interface Chassis - TSC Model TCI-1

The TCI-1 is a 15-channel common ground chassis with signal inputs switchable between sensor signals or a front panel calibration signal. Each channel has three parallel outputs. The chassis facilitates periodic calibration of selected tape and chart recorder channels.

Magnetic Tape Recorder - Honeywell Model 5600

The 5600 is a 14-channel FM Record/Reproduce System with the tape speed for this test selectable between 1 7/8 and 15 inches per second. Resulting bandwidths are DC to 625 Hz and DC to 5 kHz, respectively.

During the GVTS testing, the full scale (FS) input range was $\pm$ 5 volts while the output range was attenuated to $\pm$ 1 volt. A compensation signal was used on channel number one to minimize the effect of tape speed variations and a voice edge track was used to record all test crew communications.

Chart Recorder - Brush Model 480

The 480 is a 8-analog channel recorder with two event mark channels and features incremental drive. The drive signal is normally generated from the vehicle speed system to produce distance based charts.

During the GVTS testing, a malfunction of the speed

system dictated the use of a function-generator-derived drive signal. Conventional time-based charts resulted.

Oscilloscope - Vu-Data Model MS-201

The MS-201 is a 7-channel miniature scope with 50 mV/div sensitivity. It provides a signal display suitable for determining recordability of a given signal.

Oscilloscope - Tektronix Type 422

The 422 is a dual channel scope which provides a more detailed display of a given signal.

DATA REDUCTION

Filter - Krohn-Hite Model 3342

The 3342 is a 2-channel filter which provides additional post-test filtering of selected signals. Each channel has a selectable 8-pole high-or low-pass network with a frequency range from 0.001 Hz to 99.9 kHz.

Digital Multimeter - Data Precision Model 2440

The Model 2440 is a 4 1/2 digit meter with dc/ac voltage and resistance measurement capability.

Differential Summing Amplifier - TSC Model DSA-1

The DSA-1 is a two channel summing amplifier used to compare the signal levels from redundant sensor systems. DC accuracy is better than 0.02 percent with common mode rejection exceeding 66 dB at 500 Hz.

Chart Recorder - Beckman Type R

The type R recorder provides an 8-channel thermal writing capability with selectable gain and chart speed controls.

Spectrum Analyzer - Honeywell Model SAI-51

The SAI-51 is a real time 200-line analyzer with a digital integrator and selectable frequency ranges from 20 Hz to 1 MHz.

X-Y Plotter - Hewlett-Packard Model 7000A

The 7000A plotter provides hard copy of data output from the spectrum analyzer.

EQUIPMENT STATUS

During the GVTS Testing, all malfunctioning equipment, with the exception of the speed measurement system, was either repaired or replaced with a spare unit. The only test cancellations occurred as a result of the speed system and these tests did not bear directly on the primary test objective. The necessity of an adequate spare parts inventory is apparent in the list, tabulated in Table A-1, of equipment failures and field expedients.

CALIBRATION

All sensor subsystems were evaluated in TSC laboratories with simulated rail conditions wherever possible. Temperature cycling, vibration and shock, and voltage variations were among the simulated conditions. After all subsystems were debugged and operating to specifications, a laboratory calibration was performed. This calibration was not directly traced to a primary standard but did allow all identical components of a subsystem to be compared

TABLE A-1. TEST EQUIPMENT FAILURES AND FIELD EXPEDIENTS

Item	Failure	Field Expedient
1.	Speed Measurement System	Post-test repair at TSC
2.	Isolation Amplifier S/N 001, Chan 1	Utilized spare channel
3.	Servo Accelerometer Mode Card, CC12	Replaced with spare
4.	Signal Conditioner Master Module #32	Replaced with spare
5.	Communication Exterior Unit	Repaired
6.	Miscellaneous Cables	Replaced with spares
7.	Tape Recorder	
	a. Noise on odd channels	Repaired
	b. Malfunctioning Record Card	Replaced with spare
8.	Chart Recorder - 60 Hz Noise	Rewired input connector

relative to each other. The latter comparisons formed the basis for analyzing actual test data from redundant sensors. Because the objective of this test was to evaluate instrumentation and not vehicles, a calibration of this type was deemed adequate. Future tests on vehicles will utilize calibrated instruments traceable to the National Bureau of Standards. A calibration laboratory at the TTC is currently being established.

APPENDIX B

REFERENCE DATA SYSTEMS EVALUATION

The following test sets applicable to reference data systems are discussed in this appendix.

Test Category	Test Set	Test Title	Page
Reference Data	R42-I-5103-TT	Communications Evaluation	B-3
	R42-I-5107-TT	Rotary Pulse Generator Friction Mount Evaluation	B-8
	R42-I-5108-TT	Automatic Location Detector Evaluation	B-11
	R42-I-5109-TT	Vehicle Speed Measurement vs. Speed, Curved or Tangent Track, Wet or Dry Rails, Vehicle Direction, Comparison with Accelerometer Output.	B-25

TEST SET	TEST TITLE: Communications Evaluation TEST SET NO.: P42-I-5103-TT

TEST OBJECTIVE: To determine the operational characteristics of the sound-powered communication sets integrated with the Event/Comm Chassis, Exterior Units (CB-1), and cables.

TEST DESCRIPTION: After initial set up of the GVT reference data sensors, a TMB evaluation of the communications system was performed. All comm unit outlets were checked out and voice recording on magnetic tape was evaluated.

Any deficiencies were documented in the log and corrected; and system fidelity under simulated GVT procedures was evaluated.

STATUS: The system was installed on the vehicle and, after correction of a minor malfunction, performed satisfactorily. Fidelity of the system was adequate for test crew communications, as were the magnetic tape voice recordings during test runs.

FIGURE B-1. COMMUNICATION EVALUATION TEST SUMMARY

B1. COMMUNICATIONS EVALUATION

B1.1 TEST SUMMARY

See Figure B-1 preceding.

B1.2 PROCEDURE

The communications system was installed on the vehicle as shown in Figure B-2. Special purpose brackets were fabricated to allow mounting of the communications exterior units with existing vehicle hardware. Figure B-3 shows an exterior unit and headset. A malfunction of one of the exterior unit jacks was traced to a deformed connector, which was repaired.

Operation of all headset outlets was verified with the vehicle in the TMB. The system was then used for test crew communications during actual test runs. This voice signal was also recorded on an edge track for reference during data reduction. During one test, the voice recording was lost due to the failure of a cable connector. After replacement with a spare, operation was restored.

B1.3 INSTRUMENTATION

The communications system consists of the following items:

Event/Communications Chassis - TSC Model EC-1, 1 ea.

The TSC Model EC-1 is a 3 1/2 inch chassis mounted at the top of the middle rack in the three-bay rack assembly. It serves as the interface for all communications and event equipment. Six headset jacks are provided with the comm system single point ground connected to this chassis.

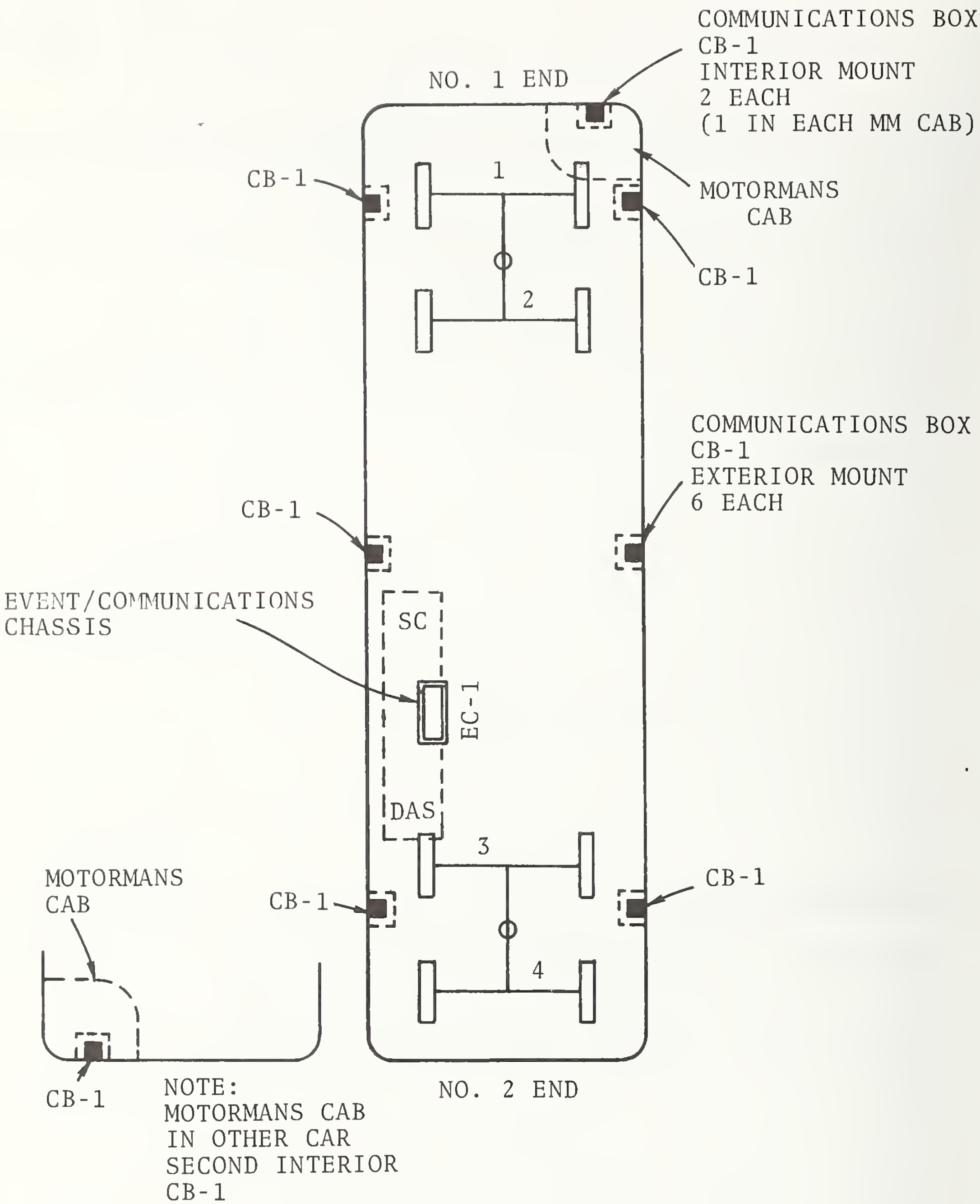


FIGURE B-2. SCHEMATIC OF COMMUNICATIONS SYSTEM TEST INSTALLATION

FIGURE B-3. COMMUNICATIONS EXTERIOR UNIT AND HEADSET

Note: Because the keyboard event equipment is designed for the digital data acquisition system, it was not evaluated during this test.

Headsets - David Clarke Models 800-SB-A, 4 ea. and 10-SB-A, 4 ea.

Model 10-SB-A is standard style while model 800-SB-A is designed for hard-hat operation. All models are self-generating (sound-powered).

Exterior Communications Units TSC Model CB-1, 8 ea.

The TSC Model CB-1 is a sealed enclosure with four headset jacks and two connectors which provides a daisy chain hookup

of several units. The comm signal and return are isolated from the metal enclosure to prevent ground loops circulating through the comm wiring.

B1.4 PRELIMINARY DATA ANALYSIS

Specific test data was not collected for this evaluation but all systems did function adequately. Subjective evaluations by test crew members indicate satisfactory performance.

TEST SET	**TEST TITLE:** Rotary Pulse Generator Friction Mount Evaluation **TEST SET NO.** R42-I-5108-TT

TEST OBJECTIVE:

1) To determine the accuracy of a friction coupling of the RPG to axle.

2) Verify operation of Axle Speed Measurement System [RPG, Cable, ASM-1 Chassis].

TEST DESCRIPTION:

Using a sophisticated event counter, the pulse output of the friction coupled RPG (2048ppr) was to be compared to the pulse output of the hard mounted Track Geometry Measurement System RPG (1000ppr). If no slippage occurred, a constant ratio would have resulted. Test was to be performed under following conditions:

a) 30 MPH - Full Loop CW
b) Widely Varying Speeds - Full Loop CW

STATUS:

A malfunction in the speed measurement system precluded detail testing per the test plan. The system has been repaired at TSC. It was observed during the RPG installation that axle and journal box relative motion exceeded one-quarter inch. Therefore, the lateral tolerance of any axially mounted friction coupling is recommended to be at least one-half inch. To insure proper speeds for other test runs, a hand held radar device was operated by the forward observer.

Because of the cancellation, details of the test are not included in this report. However, a photo of the mounted RPG is shown in Figure B-5.

FIGURE B-4. ROTARY PULSE GENERATOR FRICTION MOUNT EVALUATION TEST SUMMARY

B2. ROTARY PULSE GENERATOR FRICTION MOUNT EVALUATION

B2.1 TEST SUMMARY

See Figure B-4 preceding. A photograph of the RPG installaion is given in Figure B-5.

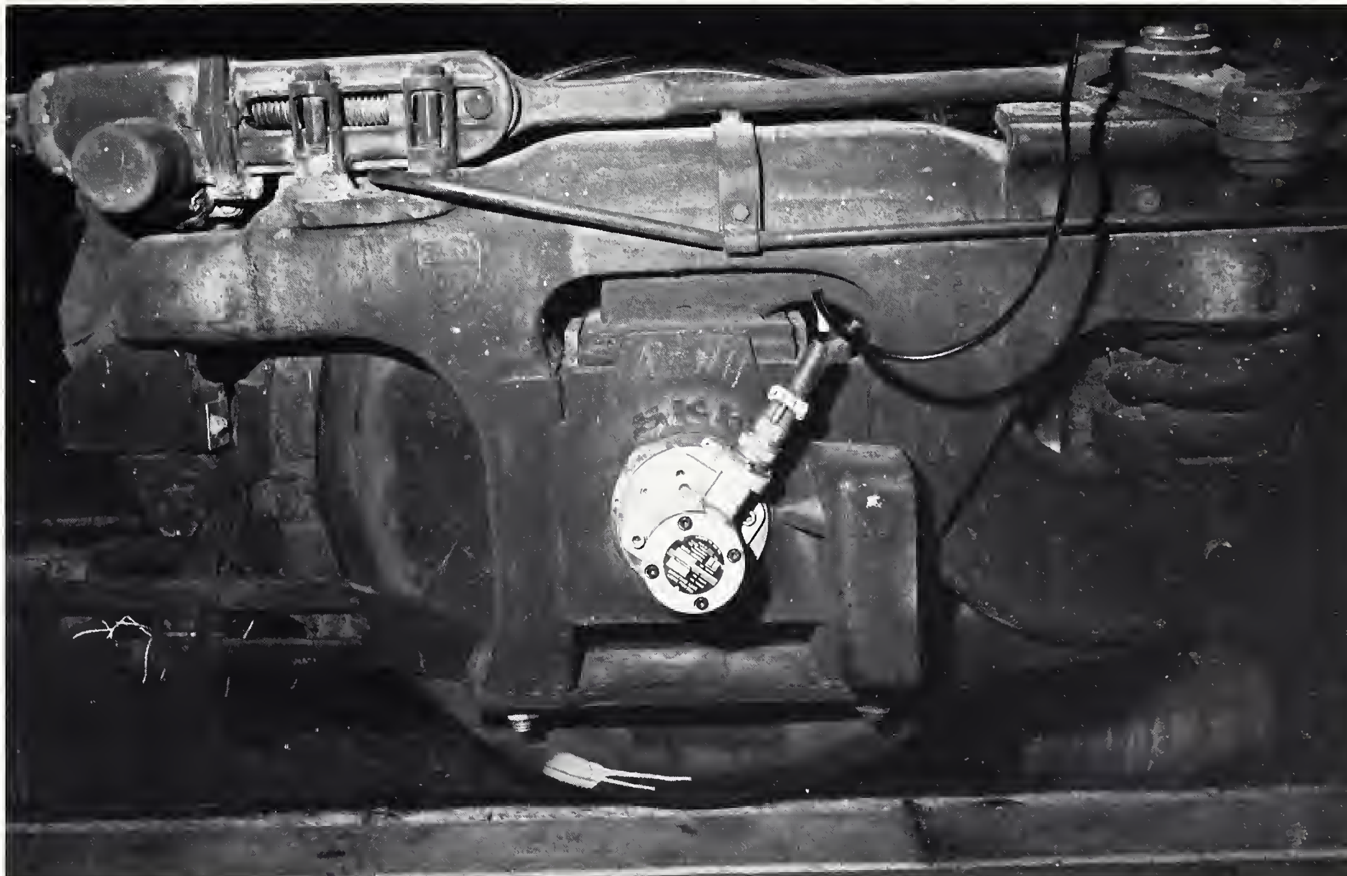


FIGURE B-5. ROTARY PULSE GENERATOR INSTALLATION

TEST SET	**TEST TITLE:** Automatic Location Detector Evaluation **TEST SET NO.:** R42-I-5108-TT

TEST OBJECTIVE: To evaluate the ALD system including: Probe, Oscillation/Demodulation, Signal Conditioning, and Cables.

TEST DESCRIPTION: Sample targets were installed on the test track roadbed. By controlling target/probe spacing and vehicle speed, the ALD operating characteristics were determined. Prime target was a series of 5 targets (2" x 6" x 1/8" ALUM) at one foot intervals located at station 150.

STATUS: The system was debugged in the field and sufficient data was recorded for evaluation. The ALD reliably detected small targets with target/probe spacings up to two inches at a vehicle speed of 55 mph. No false indications occurred after debugging.

FIGURE B-6. AUTOMATIC LOCATION DETECTOR EVALUATION TEST SUMMARY

B3. AUTOMATIC LOCATION DETECTOR EVALUATION

B3.1 TEST SUMMARY

See Figure B-6 preceding.

B3.2 PROCEDURE

The ALD system was originally used as a vehicle location reference during track geometry tests. Defects in geometry could be located a specific distance from a known track location and work crews could easily be directed to the defect location. On general vehicle tests, the ALD can be applied as:

1. A precision distance base for vehicle performance tests such as acceleration and deceleration.
2. A marker to indicate changes in track construction types around the test loop, curved and target track, and level and at-grade track. Electronic markers of this type can be used to initiate a data processing sequence.

The ALD system evaluated in this test consists of an active vehicle-mounted probe that detects the presence of metal along the centerline of the track. A sketch of the sensor location is given in Figure B-7 while a photo of the actual installation is shown in Figure B-8. The metal targets included the running rails at turnouts, 12 inch square aluminum hat sections affixed to the ties and 5 each, 2 inch by 6 inch aluminum plates mounted on a board at 1 foot intervals. The prime target was this 5 target assembly at

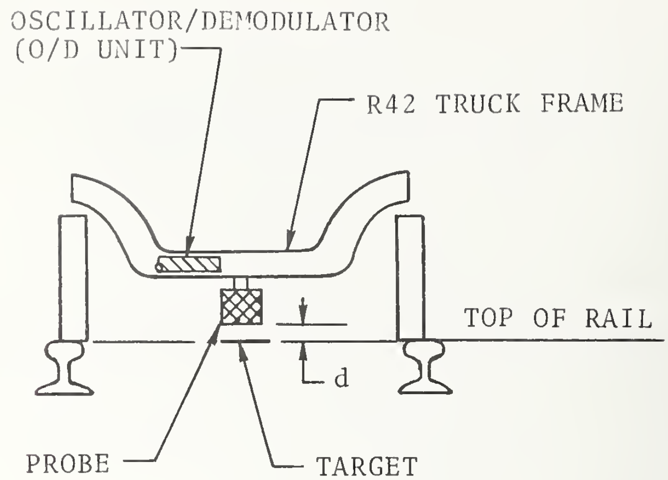


FIGURE B-7. SCHEMATIC OF AUTOMATIC LOCATION DETECTOR PROBE/ TARGET TEST INSTALLATION

station 150 which is schematically shown in Figure B-9. A total of 17 targets were located on the test loop.

To calibrate the system, a simulated target is accurately placed under the sensor and the preconditioner adjusted for proper sensitivity.

Test passes were made over the prime target at the top vehicle speed of 55 mph. Simulated service runs including top speed and braking sequences were done to monitor any false indications. The effects of target/sensor spacing were also determined by establishing known spacings and observing the output.

FIGURE B-8. AUTOMATIC LOCATION DETECTOR PROBE INSTALLATION

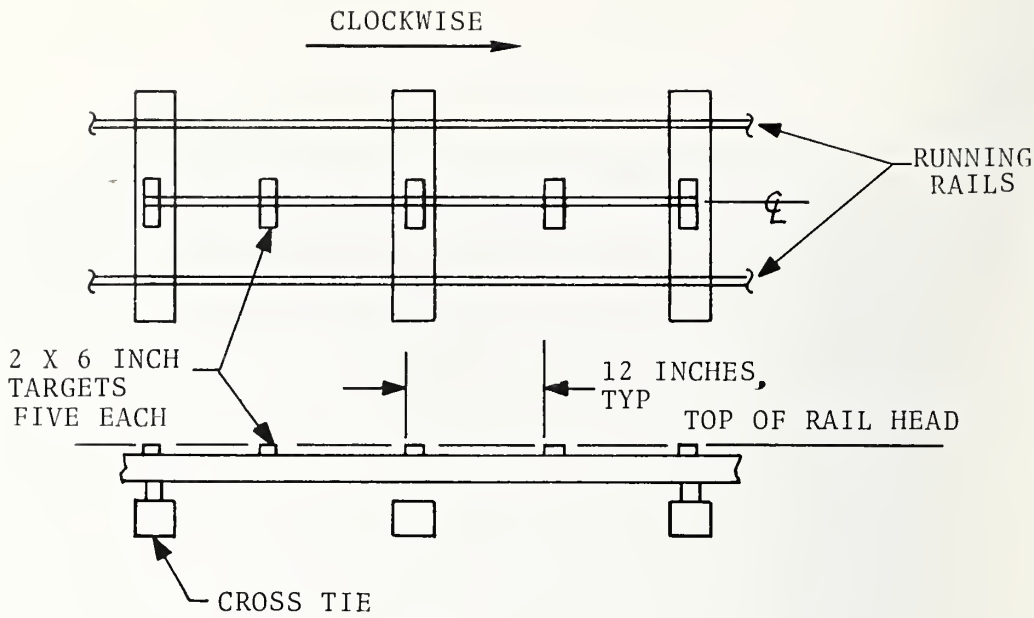


FIGURE B-9. SCHEMATIC OF AUTOMATIC LOCATION DETECTOR PRIME TARGET

B3.3 INSTRUMENTATION

A block diagram of the ALD instrumentation system for this test is shown in Figure B-10.

Sensor - Kaman Model KD 1106-10C

Preconditioner - Kaman Model KD2300-12CU

The sensor and preconditioner are normally used as a non-contact displacement measuring device that provides an output voltage proportional to the distance between the sensor and target. As an ALD, it functions only as a proximity detector with a resultant decrease in calibration complexity. Laboratory experiments indicated a single potentiometer provided adequate sensitivity adjustment.

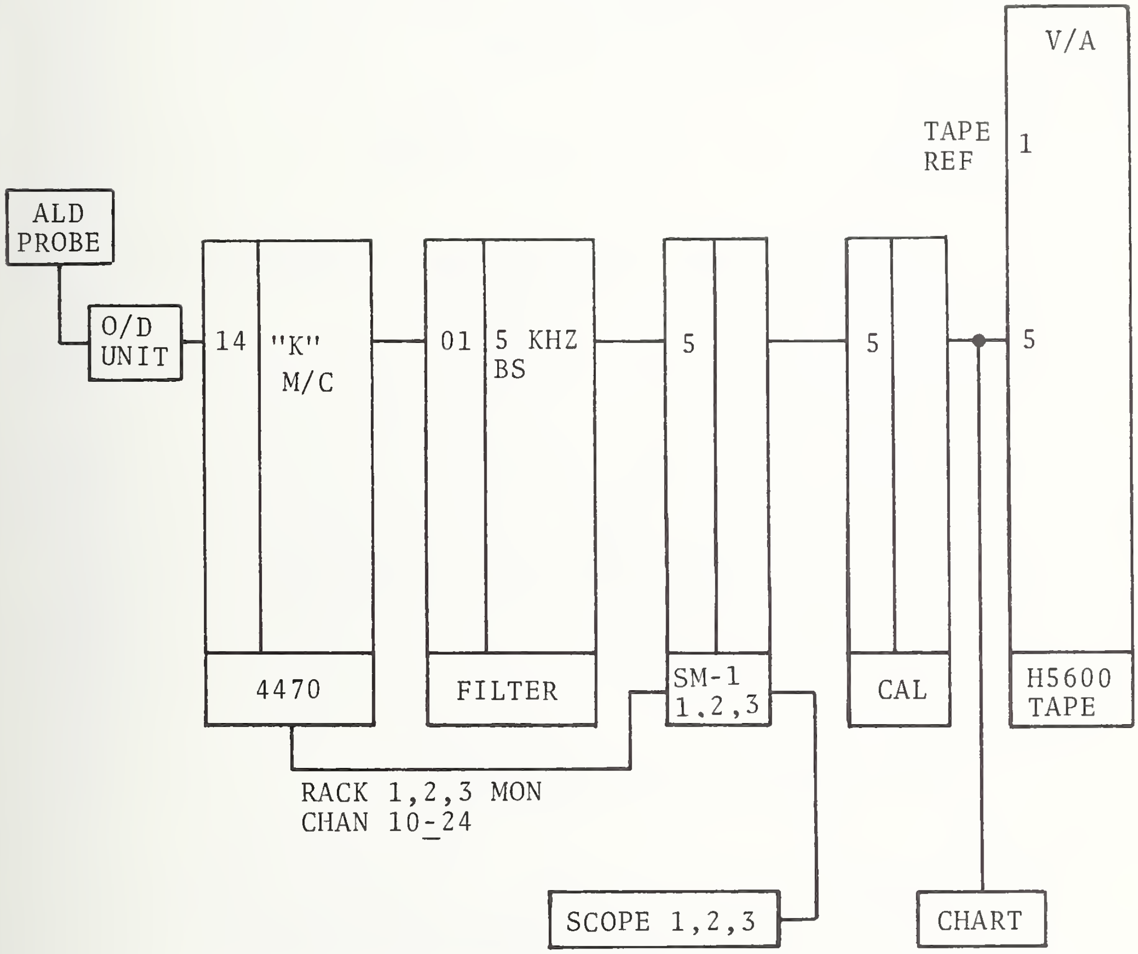


FIGURE B-10. AUTOMATIC LOCATION DETECTOR TEST EQUIPMENT BLOCK DIAGRAM

Mode Card - Endevco Model 4475.1 w/TSC Mod K

This specially designed mode card provides the required excitation voltage and signal conditioning. A TTL compatible output signal is generated as the sensor passes over a target.

The remaining items in the block diagram (Figure B-10) are discussed in Appendix A.

B3.4 PROCEDURES

I PRELIMINARY

A. Install ALD probe and electronics on vehicle per Figure B-7 with d = 1.5 inches.

B. Calibrate ALD with calibration target at 3 inches.

C. Install test targets along centerline of RTTT (Figure B-9) at Station 150. Single targets at stations 190, 310, 410.

D. Patch in General Vehicle Test electronic system per block diagram, Figure B-10, including monitor, chart, and tape.

E. Verify operation of all systems.

II TEST

A. Proceed to test zone clockwise and stop at Station 149.

B. Verify pre-test calibrations and operations.

C. Coast slowly over targets with full electronic system operational (chart - tape at 15 ips).

D. Verify tape data.

E. If pulses are missed or added, lower probe to 1-inch spacing and recalibrate with 2-inch calibration target.

F. Repeat step C.

G. If steps C and D are satisfactorily concluded, perform the following test runs:

55 MPH CW

55 MPH CCW

H. Verify the acquisition of tape data.

I. If step G produces error pulses, lower probe to 1-inch spacing and recalibrate with 2-inch target. Repeat the necessary step G runs.

J. If step G runs are completed satisfactorily, modify target board to Configuration II. (Figure B-11)

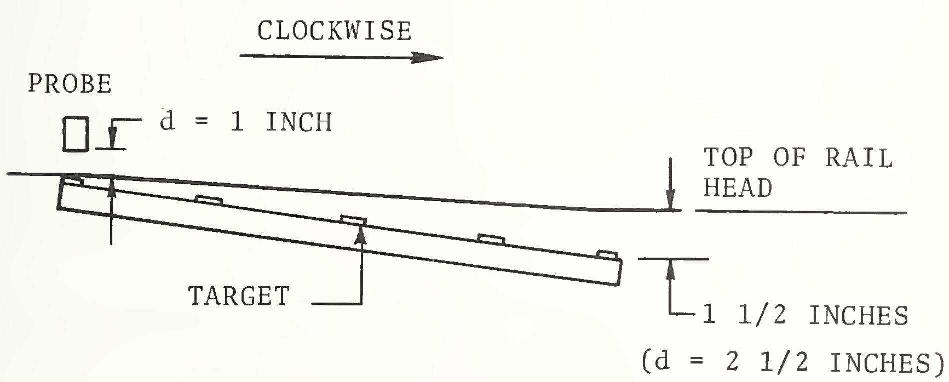


FIGURE B-11. SCHEMATIC OF AUTOMATIC LOCATION DETECTOR PRIME TARGET WITH VARYING PROBE/TARGET SPACING

K. Make CCW and CW 50-mph runs over targets. Document results.

L. Traverse the entire loop CW at widely varying speeds. Include top speed of 50 mph and full service braking sequences.

M. A forward observer will announce all ALD targets (17 ea.):

1 Turnout	Station 170
2 Target	Station 190
3 Target	Station 310
4 Target	Station 326
5 Target	Station 327
6 Target	Station 328
7 Target	Station 329
8 Target	Station 330
9 Target	Station 410 (concrete ties).
10 Turnout	Station 520
11 Turnout	Station 112
12 Turnout	Station 133
13-17 Targets	Station 150

N. Stop vehicle at Station 150. Correlate any false triggers (if possible) to vehicle braking, acceleration, etc. Reduce spacing and/or shield, if necessary. Repeat CW round trip.

Note 1: During post test processing, spurious triggers did occur but cleaning the tape heads alleviated

the problem. The random, non-repeatable spikes were not recorded on tape.

Note 2: Data in run 400/8 was recorded at 15 ips (5 kHz response) to evaluate noise levels. (10-50 mV peak noise was evident on the scope at a rep rate of 330 Hz which corresponds to the chopper frequency in the instrumentation power system.)

Post test analysis was also done on run 300/4 - Simulated Transit run. No false triggers occurred on chart or counter.

B3.5 PRELIMINARY DATA ANALYSIS

Sufficient data was collected to allow evaluation of the following system characteristics.

Optimum Target/Sensor Spacing/False Pulses

The ALD system was calibrated to trigger at 3 inch probe/target spacing for the initial runs. Many false pulses were evident, particularly as the vehicle accelerated. The (gain) sensitivity required to trigger the ALD at 3 inches is very high and stray motor fields, vibration, etc. may have caused the errors.

Following runs utilized a 2 inch spacing to set the probe trigger level. Operation of the ALD in this configuration was satisfactory with no false triggers noted on real time charts.

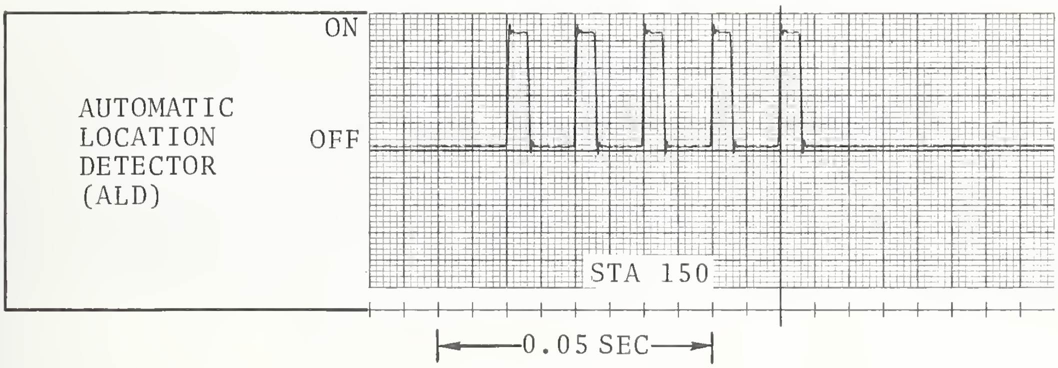
Post test analysis was done on run 400/8, a full speed CCW round trip. From the test plan, beginning at station 390, and making a full loop and stopping at 320, 22 ALD targets were specified. The real time chart, post test chart, and post test event counter all indicated 22 triggers.

Spacing Sensitivity

The five target assembly at station 150 was the prime target for ALD tests. During run 400/8, the vehicle passed over the targets at approximately 54 mph (Radar Gun Velocity). Figure B-12 is a chart record of the ALD output. To play back this data, an 8:1 speed reduction was effected (15 ips → 1 7/8 ips) and the chart speed set at a maximum of 10 cm/sec. The equivalent chart speed is 80 cm/sec. The time period between the first and last target was 49.1 msec or a 55.5 mph (81.39 ft/s) vehicle speed. The pulse widths indicate an "on" state for approximately four inches every foot. Therefore, if any time delays are neglected, triggering occurs when the leading edge of the sensor (3" dia) intersects the target by ½" and lasts until the trailing edge of sensor is one-half inch over target. See Figure B-13.

Prior to run 400/10, the five target board was slanted such that the North end was level with the rail head top and the South end was 1½" below rail head as depicted in Figure B-11. At 1.8 mph, coasting over the targets, real time charts (no tape) noted five triggers. At 57 mph, CW, four triggers occurred with the final target (d = 2 1/2") <u>not</u> detected. Figure B-14 is the chart record of this run.

When using the ALD as a precision distance base, it is necessary for the system to trigger at the same sensor/target longitudinal relationship for each target. Variances in the sensor/target spacing (d) introduce longitudinal triggering errors. To estimate this error, the "on-time" of each pulse



- RUN 400/8
- 54 MPH
- COUNTERCLOCKWISE
- FIVE TARGET ASSEMBLY
- EFFECTIVE SIGNAL BANDWIDTH - 1600 Hz

FIGURE B-12. AUTOMATIC LOCATION DETECTOR OUTPUT CHART RECORD

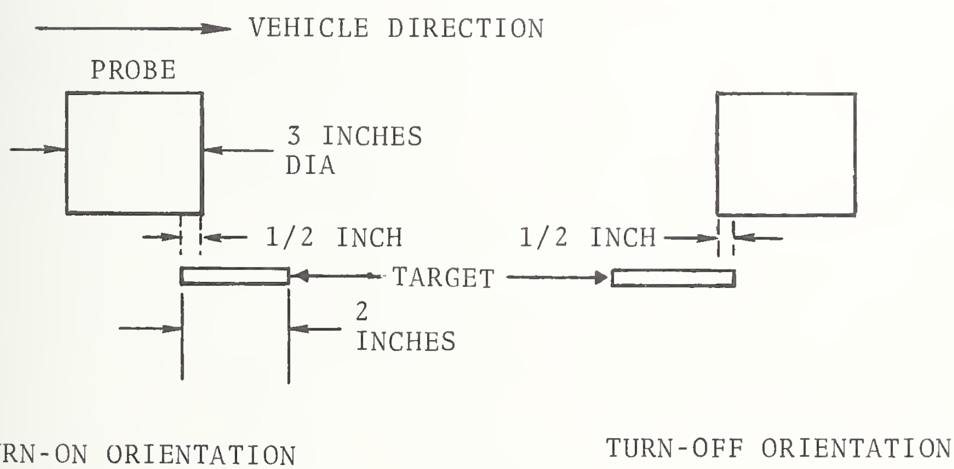
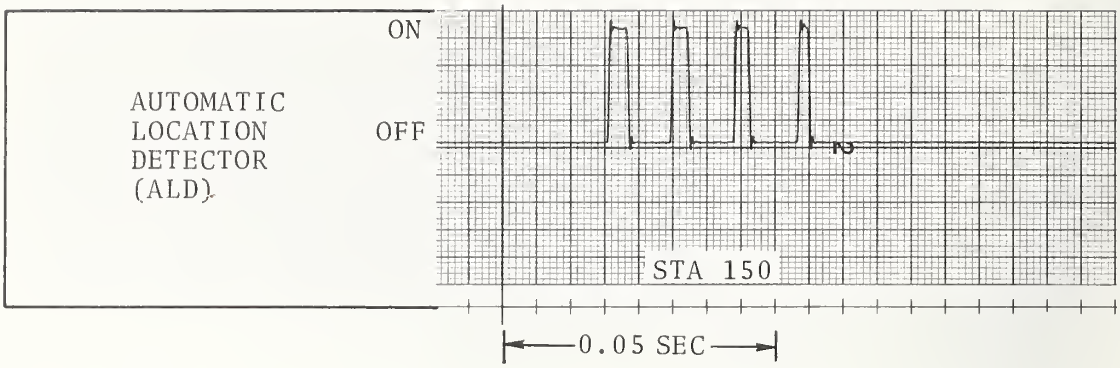


FIGURE B-13. SCHEMATIC OF AUTOMATIC LOCATION DETECTOR PROBE/TARGET ORIENTATION DURING OUTPUT SIGNAL ON/OFF TRANSITIONS



- RUN 400/10
- 57 MPH
- CLOCKWISE
- VARYING PROBE/TARGET SPACING
- EFFECTIVE SIGNAL BANDWIDTH - 1600 Hz

FIGURE B-14. AUTOMATIC LOCATION DETECTOR OUTPUT CHART RECORD

in Figure B-14 was determined. Noting the vehicle speed, an equivalent "on-distance" can be calculated and compared with the spacing. Figure B-15 is a graph of the resulting comparison.

If it is assumed that the pulse is symmetrical about the center line of the target and the leading edge was to be used to trigger a precision distance measurement, the spacing must be maintained within ±0.15 inches if the allowable triggering error is ±0.125 inches.

Speed Sensitivity

It appears that speed sensitivity is significant only if the target/probe spacing is beyond the calibrated threshold.

During the 1.8 mph coast run, the equivalent pulse width was 4" on the level target pulse. The 2 1/8" target (#4) width was 2.31 inches versus 2.13 inches at 50 + mph.

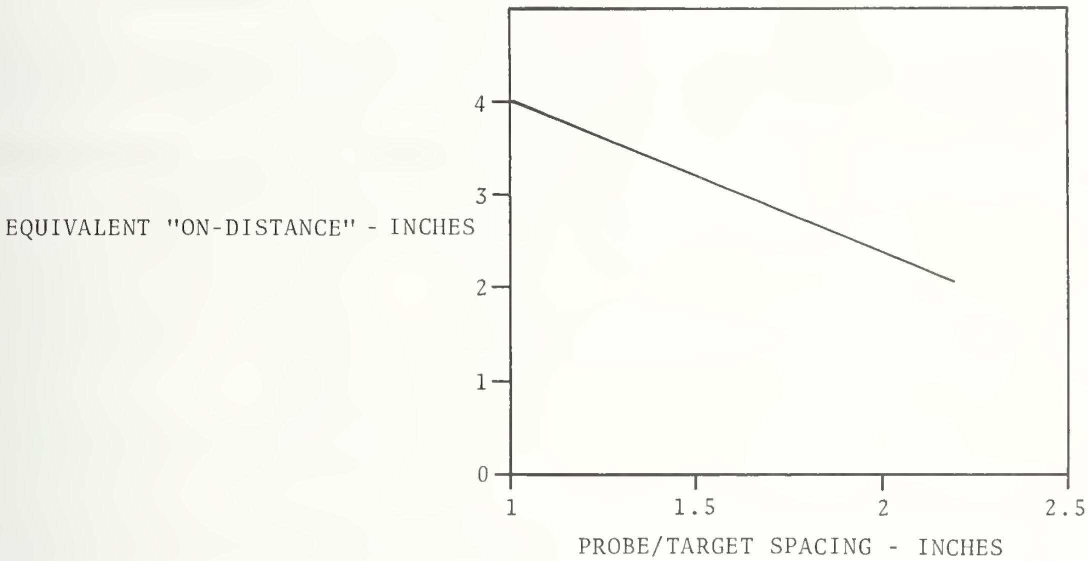


FIGURE B-15. AUTOMATIC LOCATION DETECTOR EQUIVALENT ACTUATION DISTANCE VERSUS PROBE/TARGET SPACING

TEST SET	TEST TITLE: VEHICLE SPEED MEASUREMENT VS. SPEED, CURVED OR TANGENT TRACK, WET OR DRY RAILS, VEHICLE DIRECTION, COMPARISON WITH ACCELEROMETER OUTPUT. TEST SET NO.. R42-I-5109-TT

TEST OBJECTIVE:

1) To evaluate the axle-coupled RPG as a distance measuring device under various GVT test conditions.

2) To compare a double differentiation calculation of RPG output to accelerometer output (Vehicle Performance Tests)

TEST DESCRIPTION: Two test zones were to be established

A. Sta 190 - 310 Curved Track
B. Sta 310 - 410 Tangent Track (Level @ 300-340)

The vehicle was to be operated thru the test zones in both CW and CCW directions and wet/dry rails at:
1) 20 MPH
2) 40 MPH
3) 50 MPH
4) Sample Service(2000ft. Station Interval)

In addition, special purpose accel/decel runs were to be performed on level tangent track to provide acceleration data from RPG.

STATUS: The failure of the speed measurement system forced cancellation of this test. No data was recorded and neither of the test objectives was satisfied.

FIGURE B-16. VEHICLE SPEED MEASUREMENT COMPARISON WITH ACCELEROMETER OUTPUT

B4. VEHICLE SPEED MEASUREMENT VS. SPEED, CURVED OR TANGENT TRACK, WET OR DRY RAILS, VEHICLE DIRECTION, COMPARISON WITH ACCELEROMETER OUTPUT

B4.1 TEST SUMMARY

See Figure B-16 preceding.

APPENDIX C

CURRENT AND VOLTAGE MEASUREMENT SYSTEMS

The following test sets applicable to current and voltage measurement systems, are discussed in this appendix.

Test Category	Test Set No.	Test Title	Page
Current and Voltage	R42-I-5201-TT	Current Shunt/Voltage Divider Evaluation	C-3
	R42-I-5202-TT	Current Probe Evaluation	C-33

TEST SET	TEST TITLE: Current Shunt/Voltage Divider Evaluation TEST SET NO.: R42-I-5201-TT

TEST OBJECTIVE: To determine the operational characteristics of the current shunt w/ISO amplifier and the voltage measurement systems.

TEST DESCRIPTION: The vehicle was operated under simulated GVT procedures including accel/decel and sample service. Set-up of the transducers yielded data concerning:

1. Zero signal drift
2. Noise pick-up
3. Common mode rejection
4. Redundant Data Comparison

Real time debugging of the system was accomplished with selected recording of data for further analysis.

STATUS: Sufficient data was collected to meet the test objective. An assumed malfuction of DOT 001 caused 200 volt negative spikes on the line voltage at a 525 Hz repetition rate. These spikes created artificially high common mode errors on the current shunt system. Proper filtering of the data minimized error signals. One channel of an isolation amplifier failed. The cause was undetermined.

FIGURE C-1 CURRENT SHUNT/VOLTAGE DIVIDER EVALUATION TEST SUMMARY

C1. CURRENT SHUNT/VOLTAGE DIVIDER EVALUATION

C1.1 TEST SUMMARY

See Figure C-1 preceding.

C1.2 PROCEDURE

The measurement of electrical currents and voltages is required to determine the energy consumption of the vehicle. In addition, operation of the vehicle control system can be evaluated by observing variations in current and voltage as a function of time. In this test both current and voltage measuring systems were evaluated.

To measure current, a calibrated low value resistor (shunt) was connected in series with the load. By measuring the voltage drop across this resistor, the current flow was determined by Ohm's law. The shunts used in this test were rated such that a current of 500 Amps produces a 100 millivolt signal. On the R42 vehicles, the shunts were installed prior to the load where the voltage with respect to ground exceeded 600 volts, that is; the common mode voltage (CMV) exceeded 600 volts. Conventional ground-referenced instrumentation will not withstand CMV's of this magnitude. To isolate the CMV, a differential input amplifier module with allowable CMV'S up to 5000 volts is utilized. Five commercially available amplifier modules are housed in a temperature controlled enclosure called an Isolation Amplifier Assembly, TSC Model ISO-1. All shunt signals are pre-conditioned within this assembly and the

resulting ground-referenced signal is connected with the remaining GVTS components.

Voltage measurements were made with a differential voltage divider assembly TSC Model DVD-1. Each unit contains two 200:1 voltage divider networks with the output signal differentially derived.

A simplified schematic of the R42 motor connections and sensor installation points is shown in Figure C-2. The motors are initially connected in series. Upon accelerating, the resistors, R, are gradually bypassed under command of the controller. At transition, the motor connections are paralleled and resistors, R, are connected again. As the vehicle speed increases, R's are again bypassed and field shunting occurs. A total of 18 distinct power position connections are effected during vehicle acceleration with the full cycle normally occuring in 10 to 15 seconds. To reverse the vehicle direction, the motor fields (and field shunts) are connected in the opposite polarity. During dynamic braking, the motors act as generators feeding load resistors (not shown) and the ground connection at A3 is disconnected.

The current shunts and voltage dividers were connected at points F4, FF3, and A3 as shown in Figure C-3 and C-4. The sensor nomenclature refers to the GVTP standard outputs.

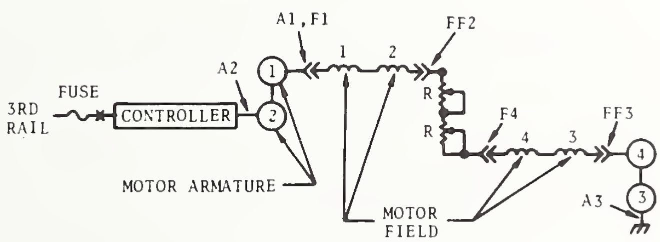
MFCD - Motor Field Current, dc

MFVD - Motor Field Voltage, dc

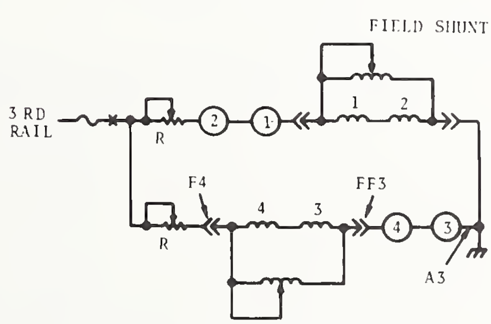
MAVD - Motor Armature Voltage, dc

The purpose for each measurement was as follows:

Voltage	MFVD-1	Grounded input - determine system noise
	MFVD-2	Ground reference V_{FF3}
	MFVD-3	Differential field voltage
	MFVD-4	Ground reference (HI) V_{F4}, $V_2 + V_3 + V_4 = 0$
	MFVD-5	Both DVD-1 leads connected to FF4; Determine CMRR
	MAVD-1	Determine voltage at A3 during dynamic braking.



SERIES CONNECTION



PARALLEL CONNECTION

FIGURE C-2. SIMPLIFIED SCHEMATIC OF THE R42 MOTOR CONNECTIONS AND SENSOR INSTALLATION POINTS

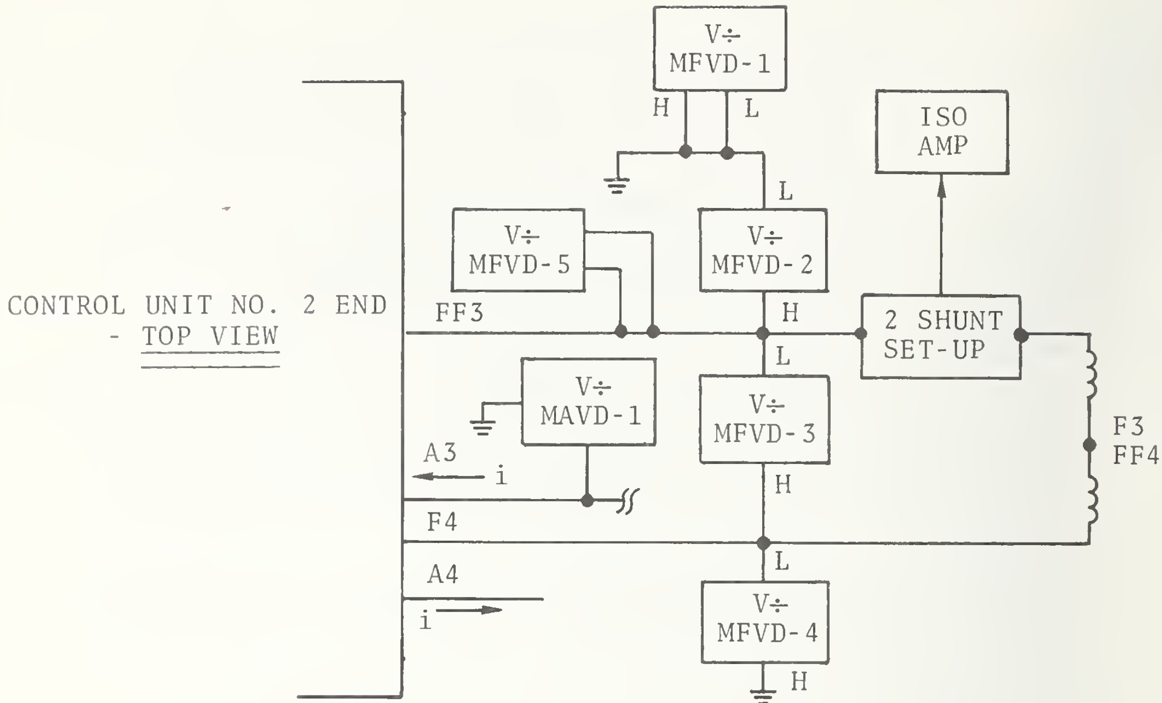


FIGURE C-3. SCHEMATIC OF VOLTAGE SENSOR TEST INSTALLATION

Current

- MFCD-1 Grounded input to ISO-1-1, determine system noise
- MFCD-2, MFCD-3 Reverse polarity signals from shunt A; $V_2 + V_3 = 0$
- MFCD-4 Redundant shunt signal; $V_4 = V_2 = -V_3$
- MFCD-5 Both ISO-1-5 leads connected to same shunt terminal. Determine CMRR.

The two shunts were installed in an insulated enclosure with jumper leads to attach to the vehicle circuits. On the R42 control unit, quick disconnect lugs are located in each motor lead. The appropriate lugs were disassembled and the shunts installed. The enclosure is shown in Figure C-5. Voltage divider connections were made by installing jumpers on the

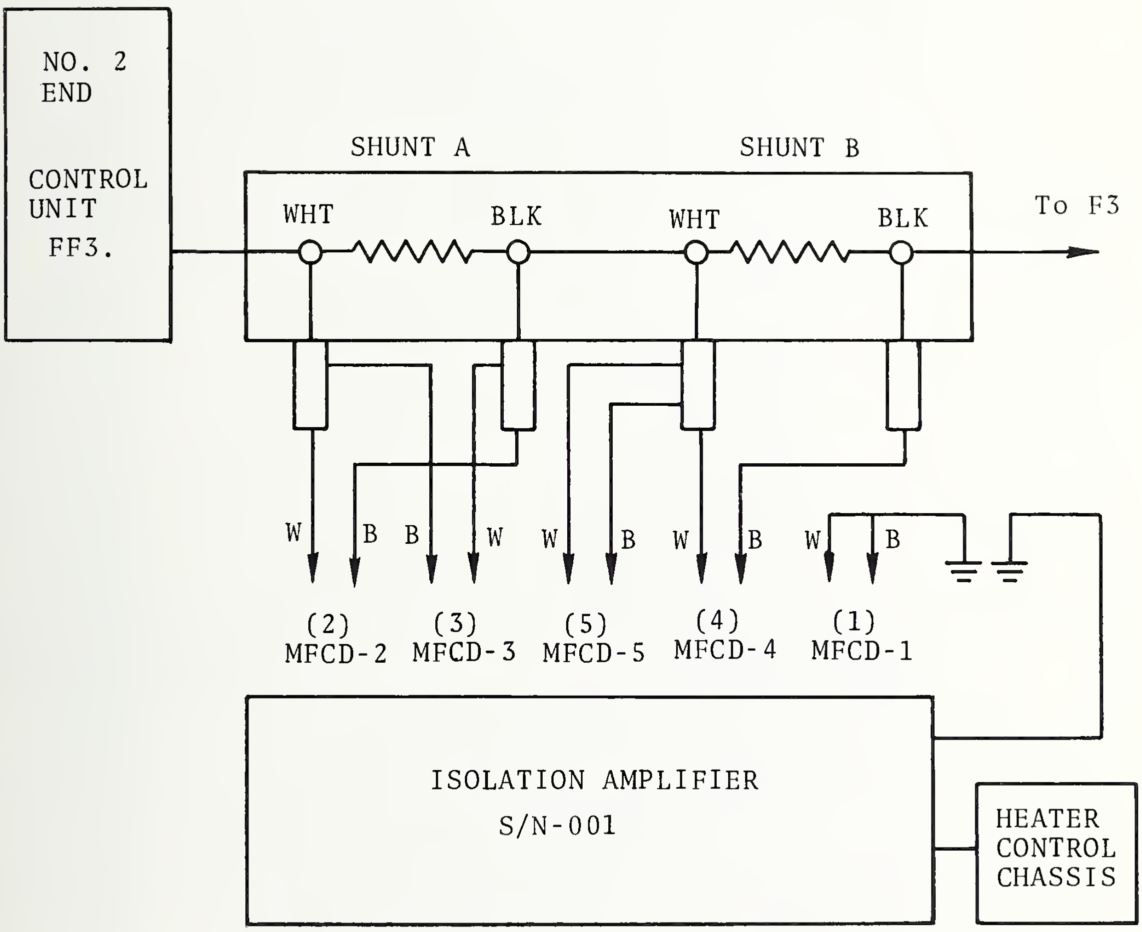


FIGURE C-4. SCHEMATIC OF CURRENT SHUNT WITH ISOLATION AMPLIFIER TEST INSTALLATION

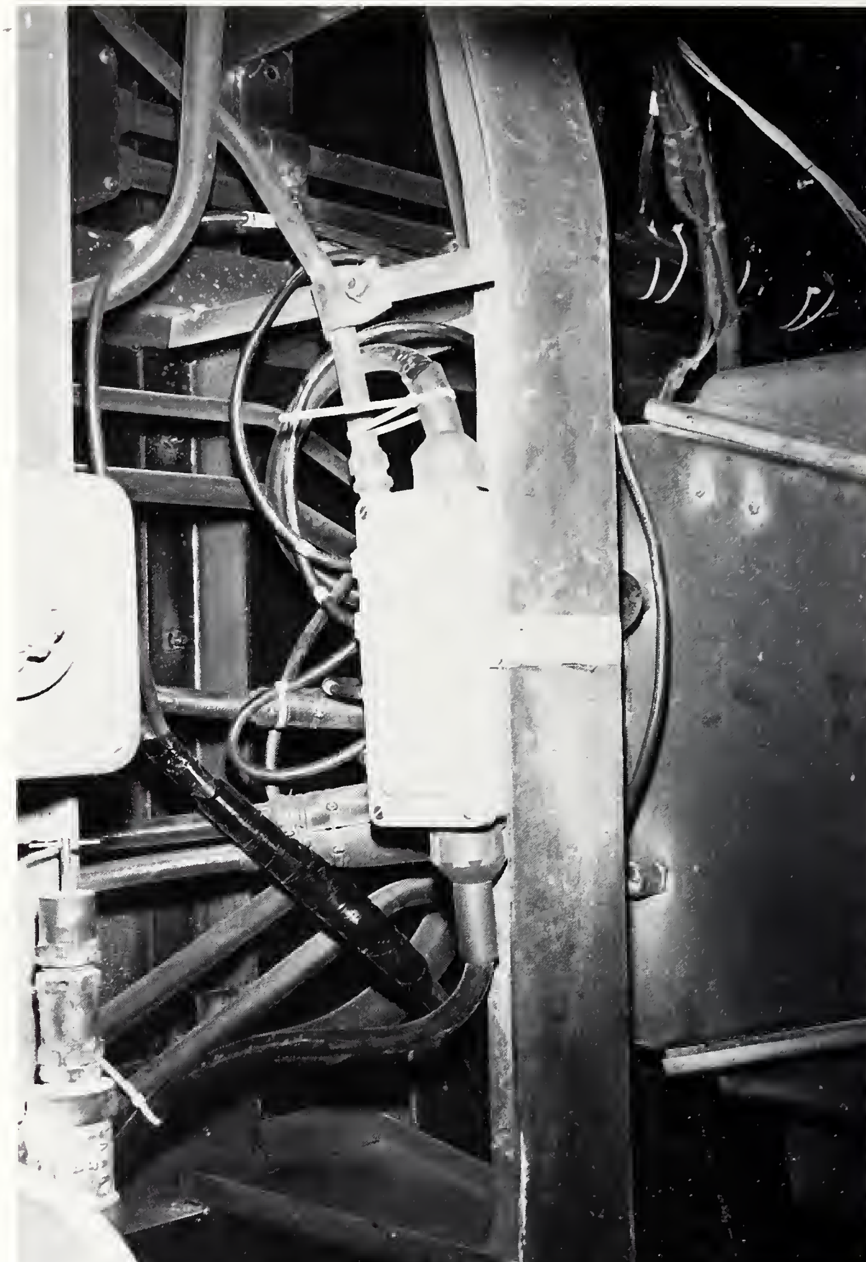


FIGURE C-5. CURRENT SHUNT ENCLOSURE INSTALLATION

appropriate contactors inside the control unit and routing these wires through existing access holes to the voltage dividers.

Seven voltage dividers and two five-channel isolation amplifiers were mounted on a TTC custom-designed metal frame. The frame was suspended beneath the vehicle near the control unit. Figure C-6 shows the installation.

To simulate actual revenue operating conditions, station stop markers were installed on the third rail cover board. The station stops utilized were identical to the synthetic transit route designed for the Advanced Concept Train (ACT I). Figure C-7 shows the locations of these stations and the ACT I speed limits. In general the R42 speeds were much less than those shown. Figure C-8 lists the station distances and also the vehicle locations where a tape recorder calibration was performed.

C1.3 INSTRUMENTATION

A block diagram of the current shunt and voltage measurement equipment for this test is shown in Figure C-9.

Sensors

Differential Voltage Divider - TSC Model DVD-1, 7 ea.

A photograph of voltage divider TSC Model DVD-1 is shown in Figure C-10.

Current Shunts A & B - Janco Model 8406B-500, 2 ea.

A current shunt with interconnections and watertight enclosure is shown in Figure C-11.

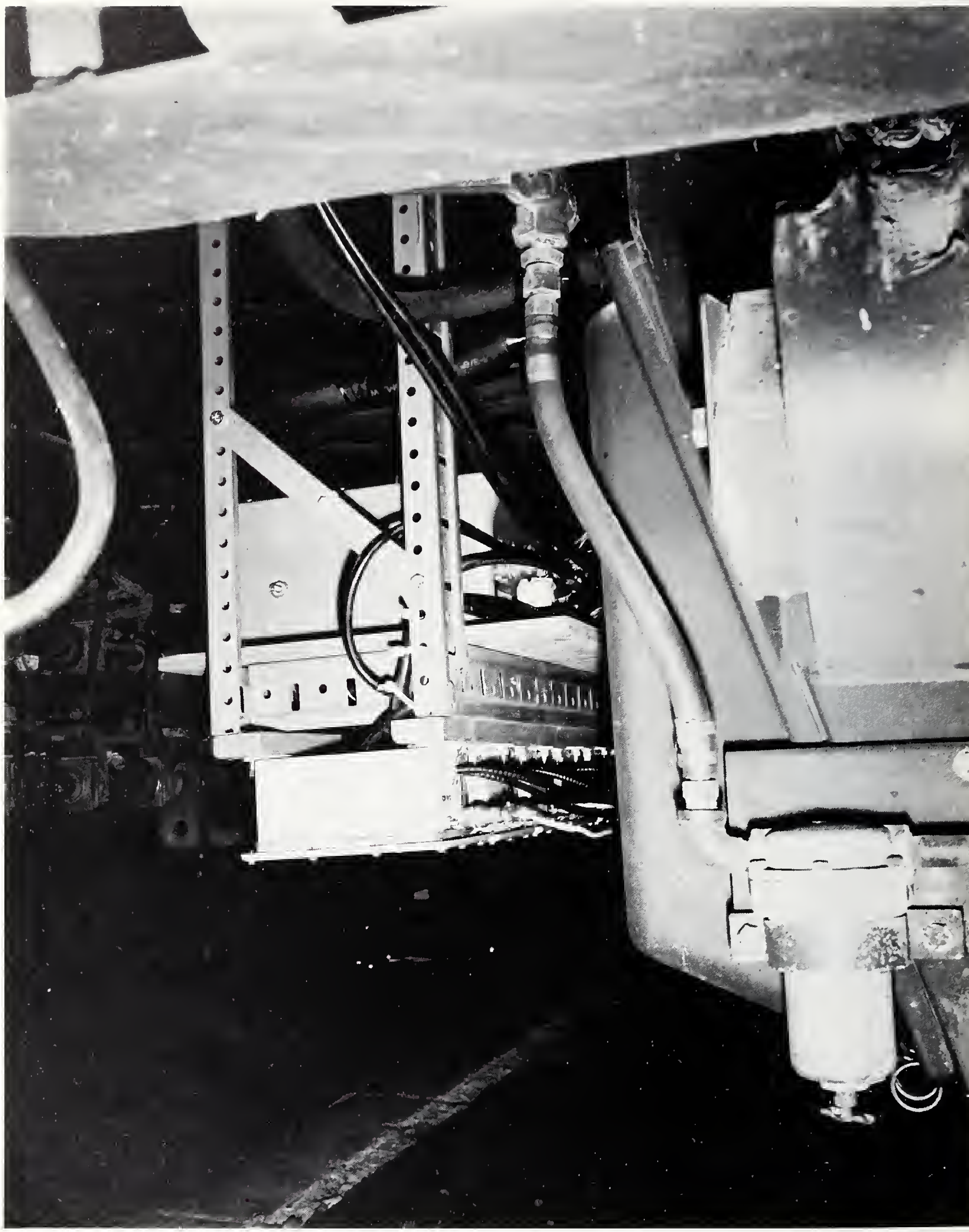


FIGURE C-6. ISOLATION AMPLIFIER/VOLTAGE DIVIDER MOUNTING FRAME INSTALLATION

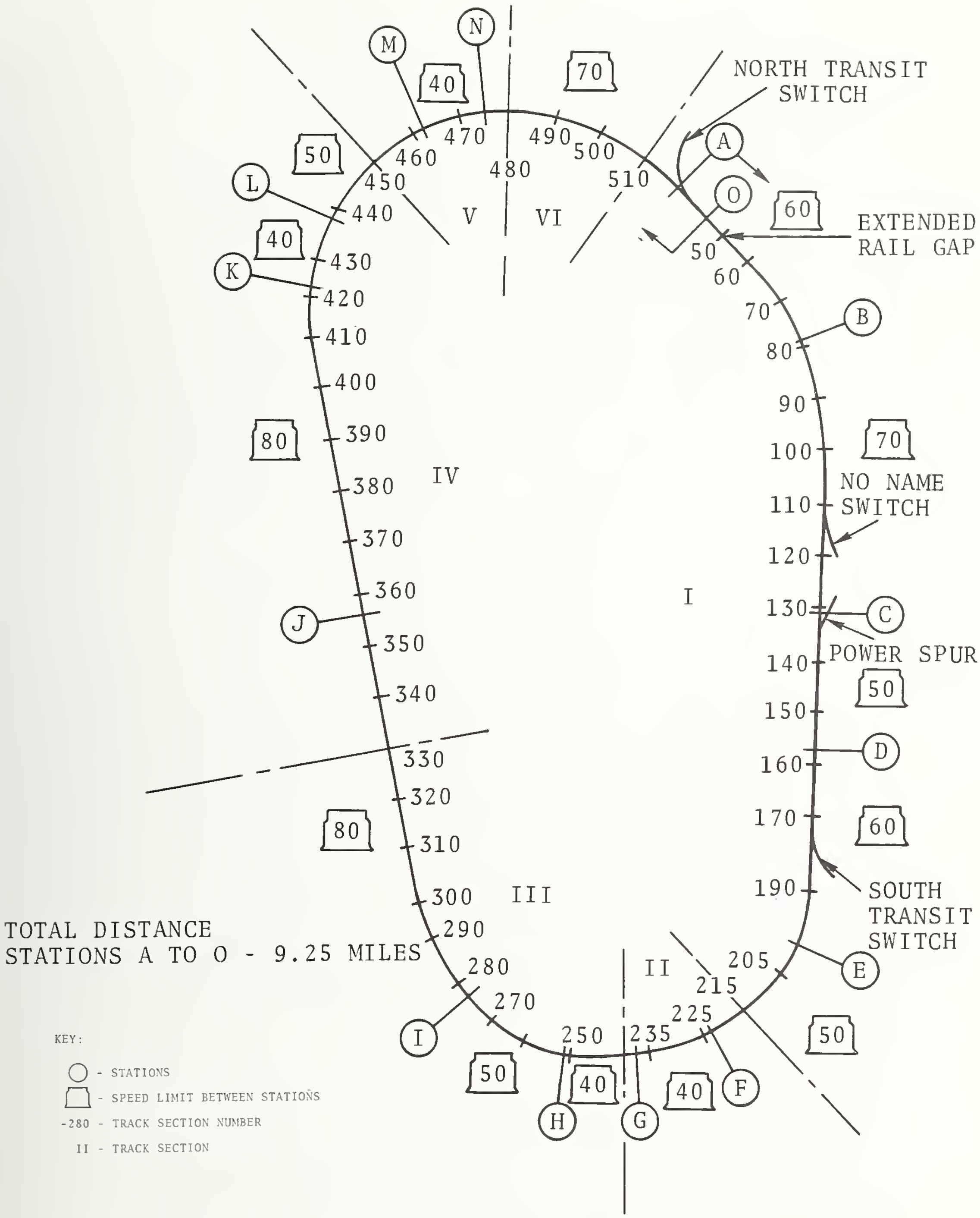


FIGURE C-7. SCHEMATIC OF SYNTHETIC TRANSIT ROUTE FOR SAMPLE SERVICE TEST RUNS

ACT I SYNTHETIC TRANSIT ROUTE

STATION		DISTANCE (MILES)
RECORDER CALIBRATE	1 MIN.	
A to B		.75
B to C		1.00
C to D		.50
D to E		.75
RECORDER ZERO	1 MIN.	
E to F		.50
F to G		.25
G to H		.25
H to I		.50
I to J		1.50
RECORDER ZERO	1 MIN.	
J to K		1.25
K to L		.25
L to M		.50
M to N		.25
N to O		1.00
RECORDER CALIBRATE	1 MIN.	

FIGURE C-8. SYNTHETIC TRANSIT ROUTE STATION DISTANCES AND TAPE RECORDER CALIBRATION LOCATIONS

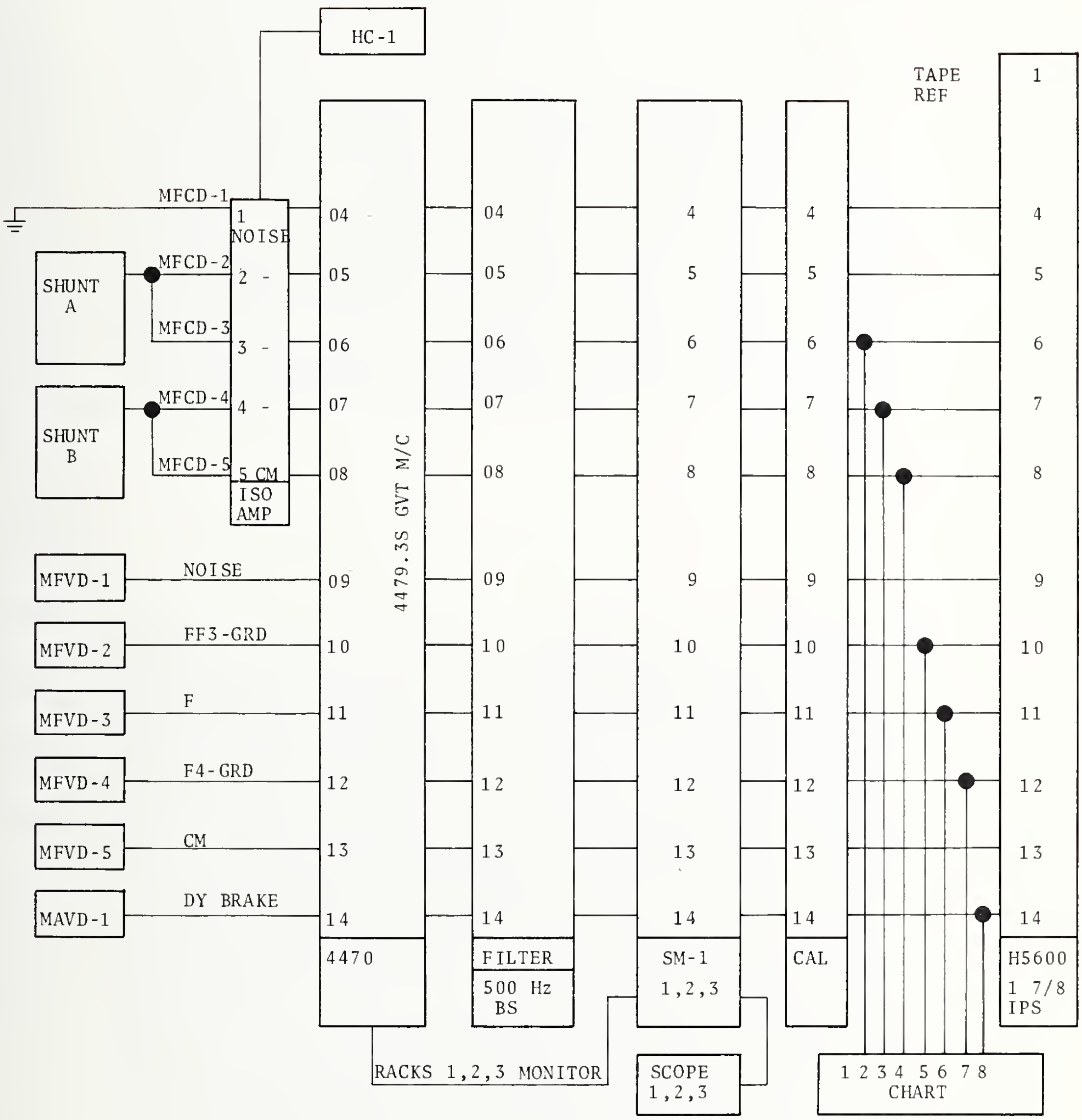


FIGURE C-9. CURRENT SHUNT AND VOLTAGE DIVIDER TEST EQUIPMENT, BLOCK DIAGRAM

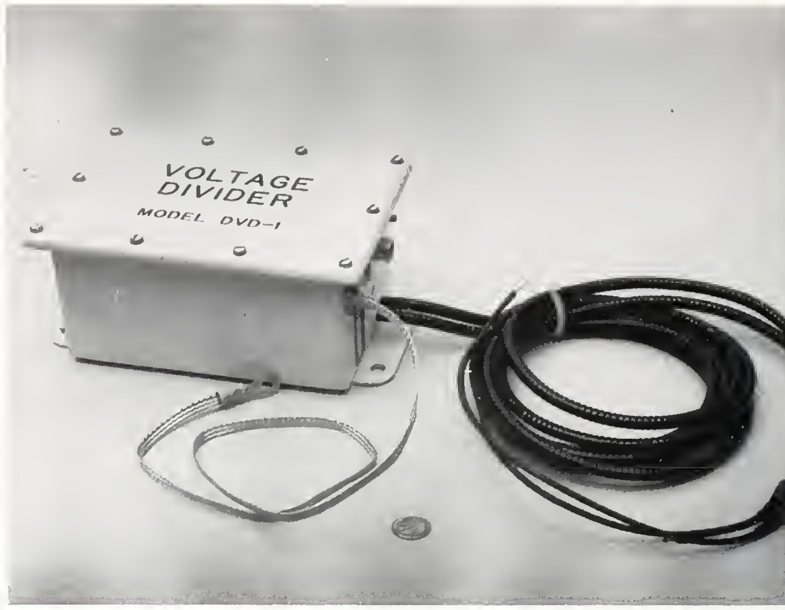


FIGURE C-10. VOLTAGE DIVIDER, TSC MODEL DVD-1

FIGURE C-11. CURRENT SHUNT INSTALLATION ENCLOSURE

Preconditioner

Isolation Amplifier - TSC Model ISO-1

One five-channel unit is shown in Figure C-12. The cover is removed to reveal the heater blankets surrounding the inner case.

Control/Interface

Heater Control Chassis - TSC Model HC-1

This two-channel chassis provided 115 volt ac power for the isolation amplifier thermal control system. A current meter and fault light were utilized to monitor heater operation.

Mode Card - TSC Model 4479.3S

This TSC designed GVT mode card features a differential input with gains of 1, 10, 50, or 100. It is used with both current shunt and voltage divider systems.

Remaining items in the block diagram are discussed in Appendix A.

C1.4 PROCEDURES

I PRELIMINARY

A. Install test equipment as shown in Figures C-3, C-4, and C-9.

B. Verify signal routing by simulation.

C. Complete log documentation sheets.

II TEST

A. Proceed to test loop.

B. Verify system operation.

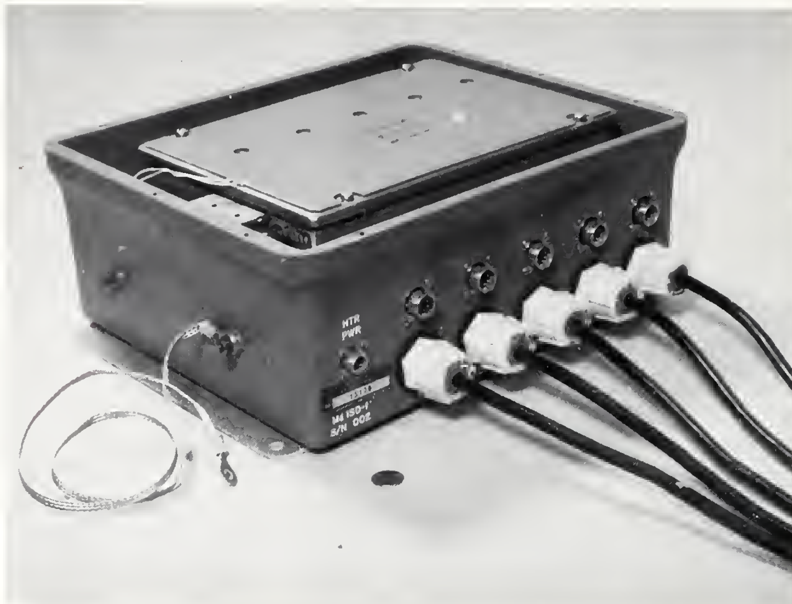


FIGURE C-12. ISOLATION AMPLIFIER ASSEMBLY, TSC MODEL ISO-1 (COVER REMOVED)

C. Calibrate tape unit: one minute at 0.0 volts, one minute at 5.0 volts.

D. Power rail.

E. Verify heater warmup.

F. Observe zero signal levels on scope.

G. Operate vehicle on command of Chief Test Engineer.

H. Debug and document all problems on each channel.

I. Operate vehicle in a sample service mode described in the three following steps, and in Figures C-7 and C-8:

   1. Use synthetic transit route CW beginning at Station A.

2. Calibrate recorder at station stops A, E, J, O.

3. Zero signal conditioners prior to run.

C1.5 PRELIMINARY DATA ANALYSIS

Data for this test was collected on analog magnetic tape at 1 7/8 and 15 ips and processed at TSC. The discussion of the analyzed data is divided into voltage divider data and current shunt data.

C1.5.1 Voltage Divider Data Analysis

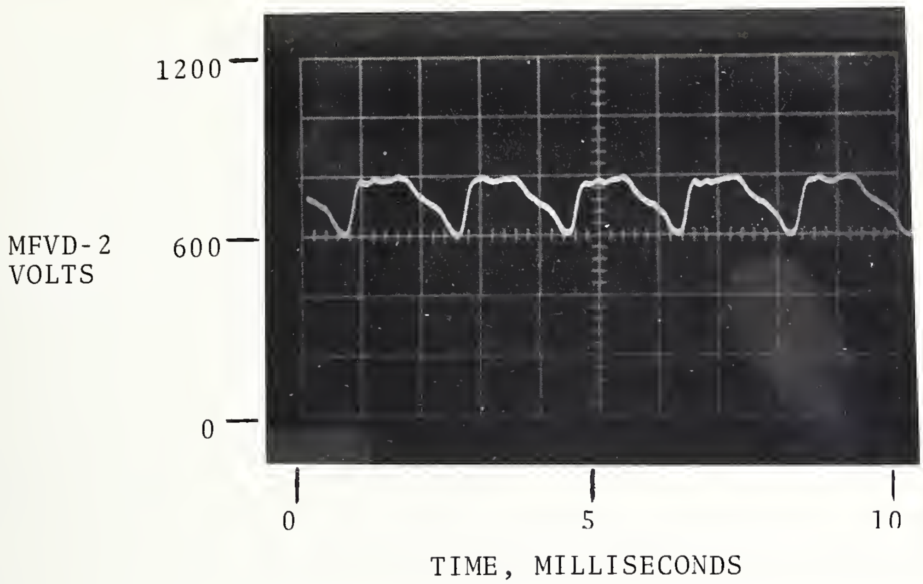
A portion of a chart recording is shown in Figure C-13. The chart displays voltage divider data from run 200/6, a clockwise sample service run. Parameters MFVD-1 through MFVD-5 are shown on channels 1 through 5, respectively. By observing the chart of the entire run, measuring DC voltage levels, and performing frequency spectrum analyses, the voltage divider measurement system was evaluated.

The nominal voltage supplied by the DOT-001 locomotive to the R42 vehicle is 600 volts dc. The ripple is specified to be less then 5 percent. The voltage actually supplied during this test was characterized by 200 volt negative spikes at a repetition rate of 525 Hz. The possibility of a failure in the DOT-001 circuitry is being investigated. When the voltage signal was recorded, its bandwidth was limited to 5 kHz (15 ips tape speed) or 500 Hz (1 7/8 ips).

Figures C-14 and C-15 are photographs of oscilloscope traces of the MFVD-2 signals from two counterclockwise runs at 15 and 1 7/8 ips recording speeds. The effects of the signal

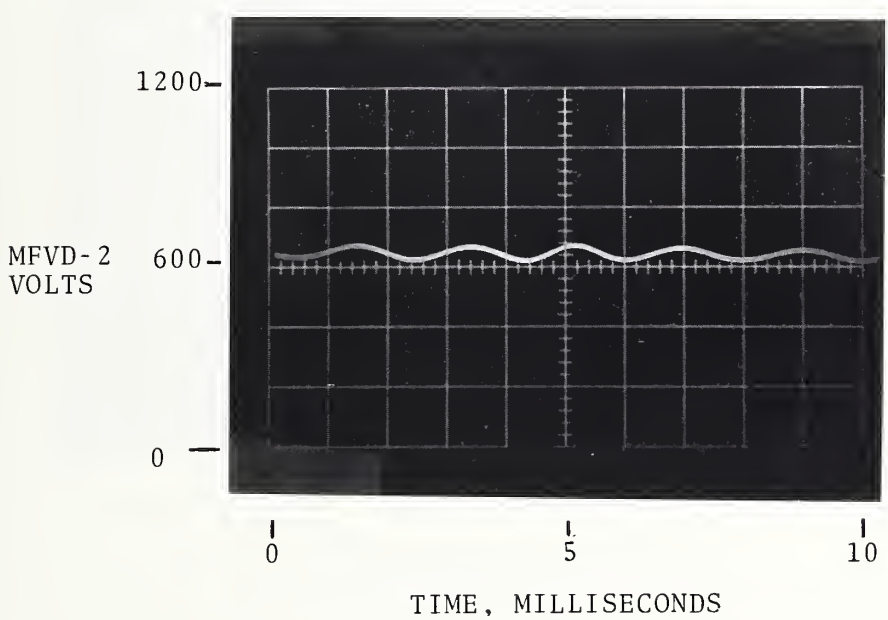
- RUN 200/6
- SAMPLE SERVICE
- CLOCKWISE
- SIGNAL BANDWIDTH - 40 Hz.

FIGURE C-13. VOLTAGE SIGNAL CHART RECORD



- RUN 200/7
- CONSTANT SPEED
- COUNTERCLOCKWISE
- SIGNAL BANDWIDTH - 5 KHz

FIGURE C-14. VOLTAGE SIGNAL MFVD-2 OSCILLOSCOPE TRACE



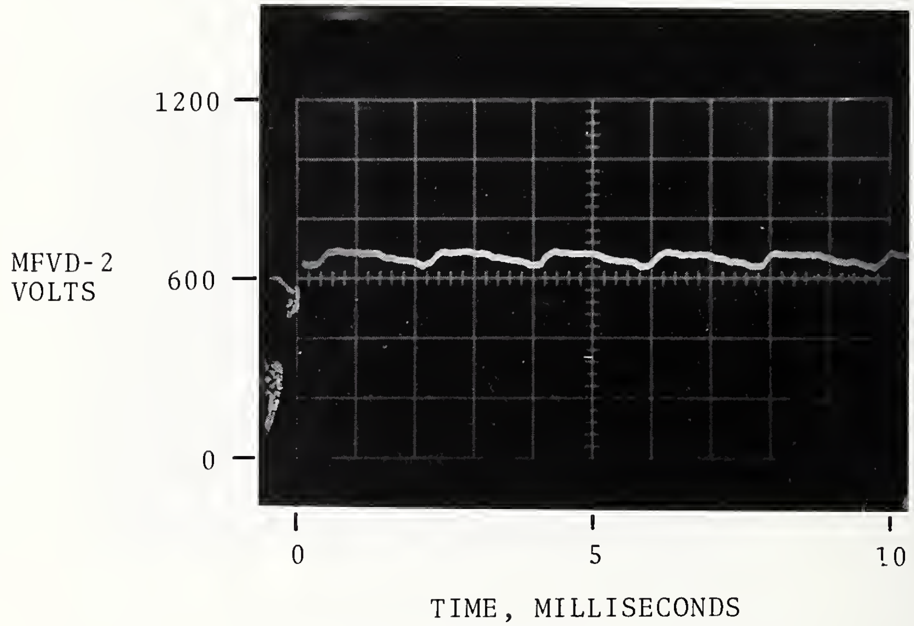
- RUN 200/5
- CONSTANT SPEED
- COUNTERCLOCKWISE
- SIGNAL BANDWIDTH - 500 Hz

FIGURE C-15. VOLTAGE SIGNAL MFVD-2 OSCILLOSCOPE TRACE

bandwidth are obvious. During clockwise test runs (Figure C-16, 15 ips) the voltage spikes were reduced because the fields were connected in the opposite polarity and filtered the spikes.

Zero Signal Drift

The voltage dividers contain computer grade, high voltage resistors. Each divider network was matched in ratio value and temperature coefficient. When the vehicle was stationary, the voltage across any one voltage divider was zero. By periodically monitoring the zero signal output voltage, the system drift was determined. After compensating for tape drift, the sensor zero shift was +0.1% full scale on MFVD-1 and MFVD-5 and 0.0% on MFVD-2 through MFVD-4.



- RUN 200/7
- CONSTANT SPEED
- CLOCKWISE
- SIGNAL BANDWIDTH - 5 KHz

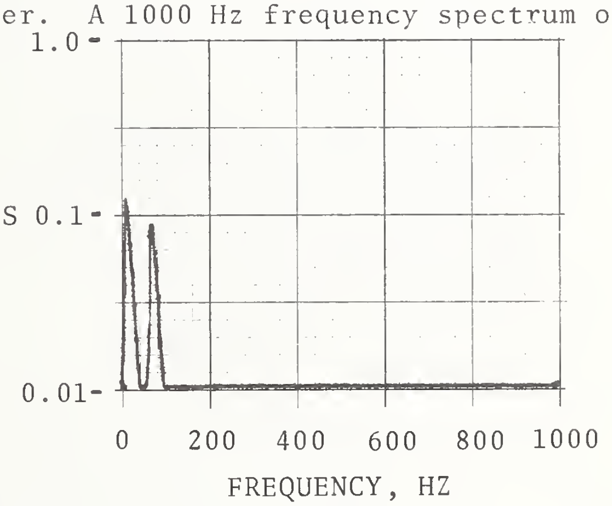
FIGURE C-16. VOLTAGE SIGNAL MFVD-2 OSCILLOSCOPE TRACE

Noise Pick-up

The MFVD-1 voltage divider had both input leads connected to ground. A zero signal output should occur independent of vehicle operation. The chart recording (±2% FS) displayed no dependence on other data signals. A 1000 Hz frequency spectrum taken from run 200/6 with the tape at 15 ips is shown in Figure C-17. The peak at 60 Hz is only 0.09% of the full scale signal level.

Common Mode Rejection Radio (CMRR)

The MFVD-5 had both high voltage input leads connected to FF3. Ideally, a zero signal would result. The MFVD-5 was compared to MFVD-2, the common mode voltage. No dc component was evident in the chart, but ac reactions to the voltage transients did exist. These were probably caused by unmatched high frequency characteristics of the volt divider. A 1000 Hz frequency spectrum of



- RUN 200/7
- COUNTERCLOCKWISE
- SAMPLE SERVICE
- 1000 HZ RANGE

NOTE: 1.0% FS OF THE TAPE RECORDER OUTPUT CORRESPONDS TO A 10 MV PEAK DISCRETE FREQUENCY SINE WAVE USED TO CALIBRATE THE SPECTRUM ANALYZER.

FIGURE C-17. VOLTAGE NOISE SIGNAL MFVD-1 FREQUENCY SPECTRUM

both signals indicate the CMRR of the volt divider at 525 Hz is 24 dB. The resultant CM error signal however is 50 dB below FS level. It is noted that normal installations of the voltage divider will not subject the unit to CMV's of this magnitude.

Redundant Data Comparison

Sensors MFVD-2 through MFVD-4 were installed across the motor fields such that their signal summation equaled zero. The signals were summed using a digital voltmeter at five locations along the test track. The maximum dc error was within $\pm 0.5\%$ FS.

Armature Voltage During Dynamic Brake

On dynamic brake, the armature A3 is disconnected from train ground and allowed to float while the motors act as generators supplying the brake resistor grid. The voltage above ground at this point exceeded 1500 volts.

C1.5.2 Current Shunt Data Analysis

The test run chosen for discussion was 200/6. This run was a sample service run in the clockwise direction. The run lasted 26 minutes.

Zero Signal Drift

When the vehicle stopped, the motor field current was reduced to zero amps. By measuring the output signals corresponding to the zero level input at various locations around the track, the zero drift of each sensor system was determined. The tape channel drift was compensated when determining the sensor drift values. The maximum zero drift of each system was:

MFCD-1	0.0% FS
MFCD-2	+.1% FS
MFCD-3	-.1% FS
MFCD-4	+.2% FS
MFCD-5	+.2% FS

Noise Pick-up

Sensor MFCD-1 featured both high and low isolation amplifier leads connected to train ground. The 20 foot input cable was routed along with the four other shunt cables. A malfunction of the MFCD-1 isolation amplifier channel forced this grounded input signal to be placed on channel 5 of the other isolation amplifier. Time did not permit proper routing of the cable and it remained tightly coiled attached to the mounting frame. Figure C-18 displays data from run 200/6. MFCD-1 exhibits an error of approximately 1.5 percent that appears to correlate with the motor field voltage, MFVD-2. The error is not evident on MFCD-5 where both input leads were connected to FF3. It is theorized that the coiled input cable adversely affected the data signal.

The chart recorded data has a frequency response of 40 Hz. To examine higher frequency noise, frequency spectra are shown in Figure C-19. The tape recorder noise level during a zero volt calibration is shown in Figure C-19(a) while the MFCD-1 system noise is shown in Figure C-19(b). The spectra indicate signal noise components in the 0-200 Hz range at approximately 0.03 percent FS.

Common Mode Rejection Ratio (CMRR)

Figure C-20 is a plot of the CMRR versus frequency of the isolation amplifier system. The values were determined in laboratory

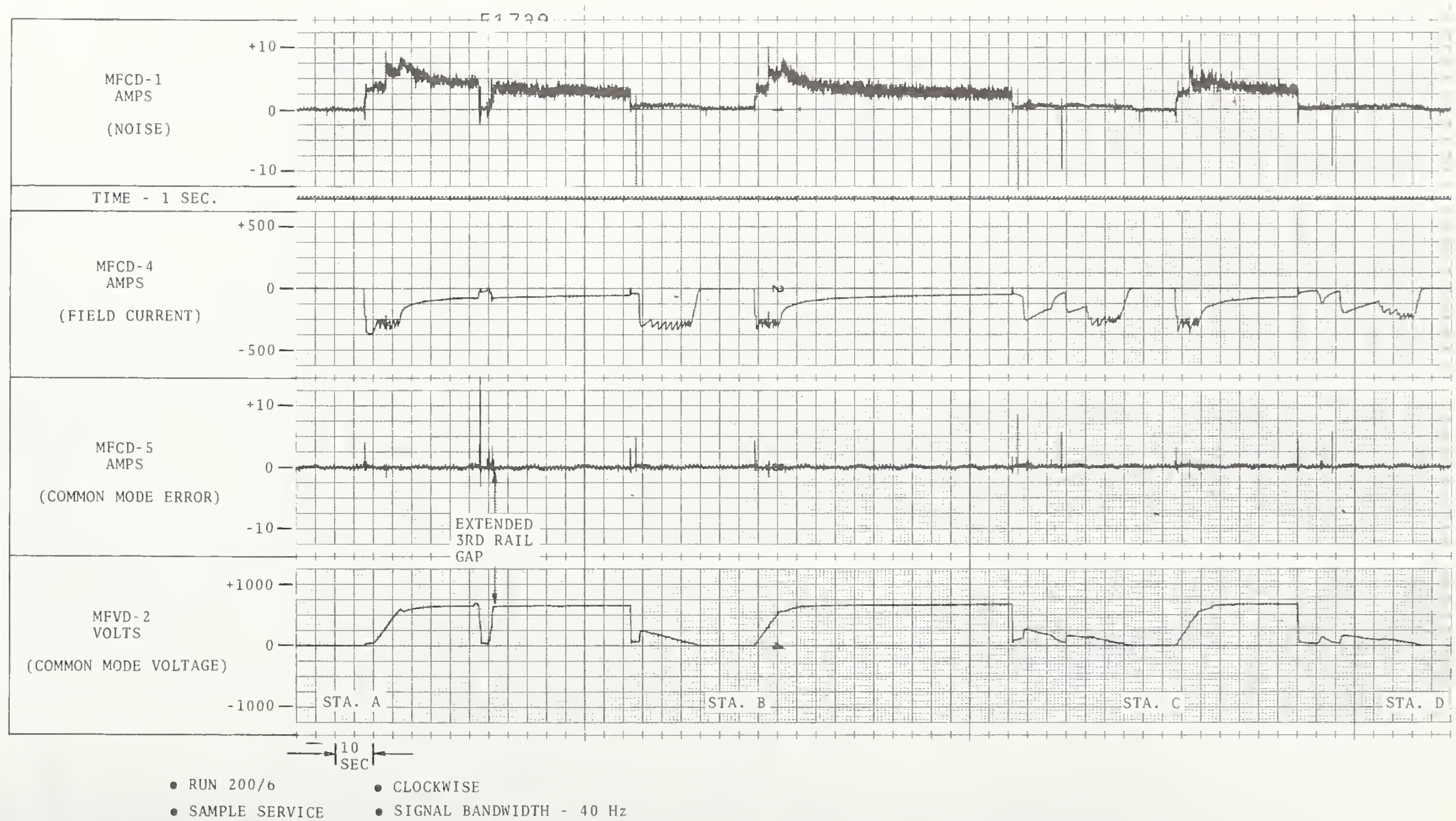
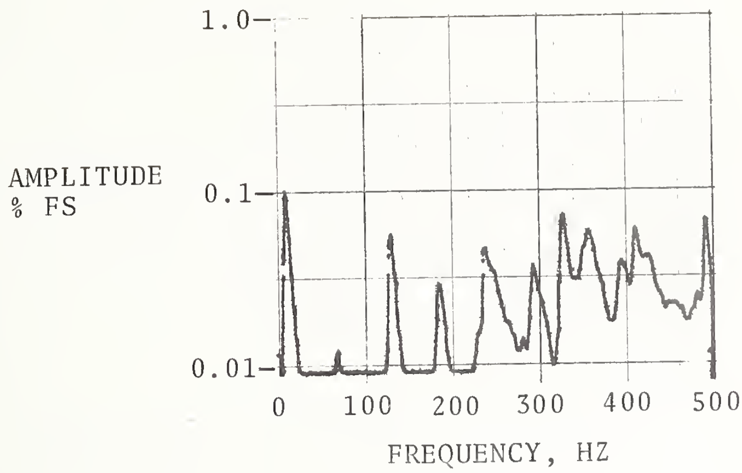
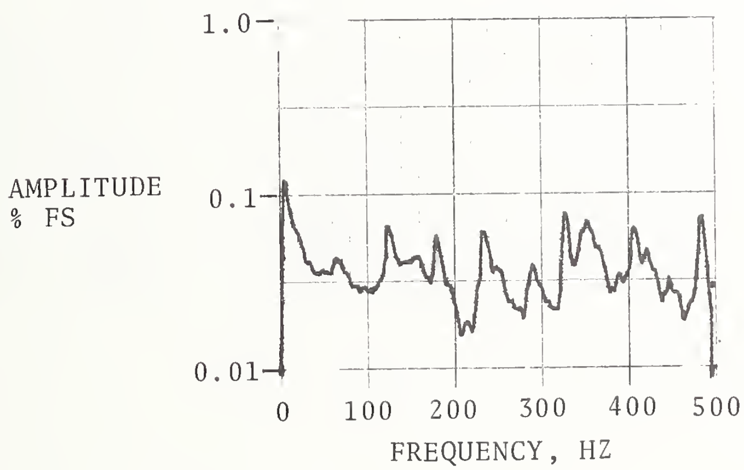


FIGURE C-18. CURRENT SHUNT AND VOLTAGE SIGNAL CHART RECORD



TAPE NOISE (TN)

FIGURE C-19(a)



SIGNAL NOISE (SN)

FIGURE C-19(b)

- RUN 200/6
- CLOCKWISE
- 40 MPH CONSTANT SPEED
- 500 Hz

NOTE: 1.0% FS OF THE TAPE RECORDER OUTPUT CORRESPONDS TO A 10 MV PEAK DISCRETE FREQUENCY SINE WAVE USED TO CALIBRATE THE SPECTRUM ANALYZER.

FIGURE C-19. CURRENT SHUNT NOISE SIGNAL MFCD-1 FREQUENCY SPECTRA

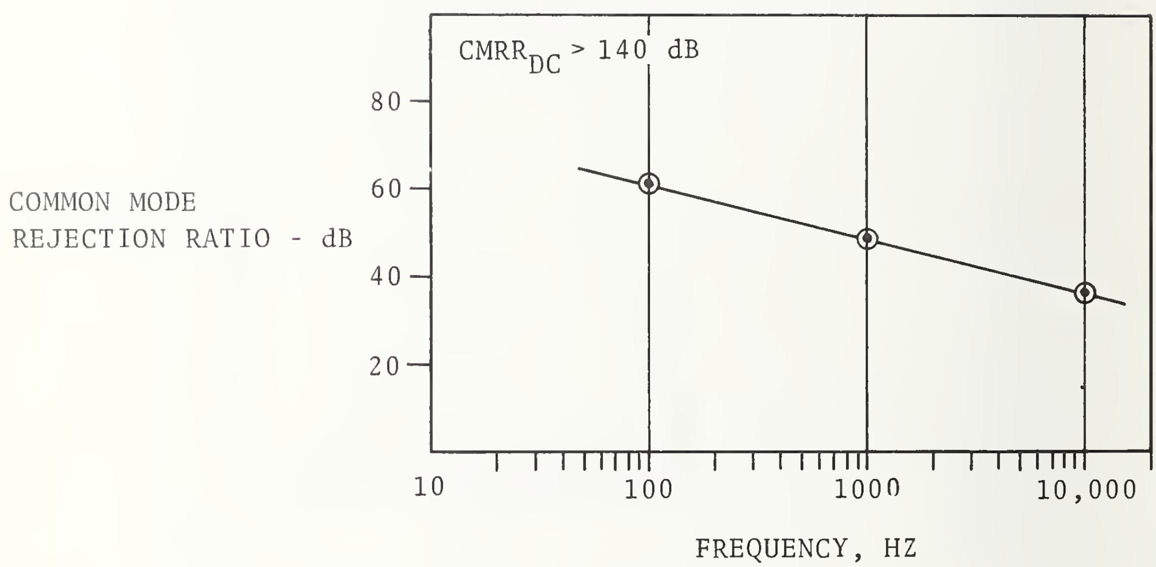


FIGURE C-20. ISOLATION AMPLIFIER COMMON MODE REJECTION RATIO VERSUS FREQUENCY

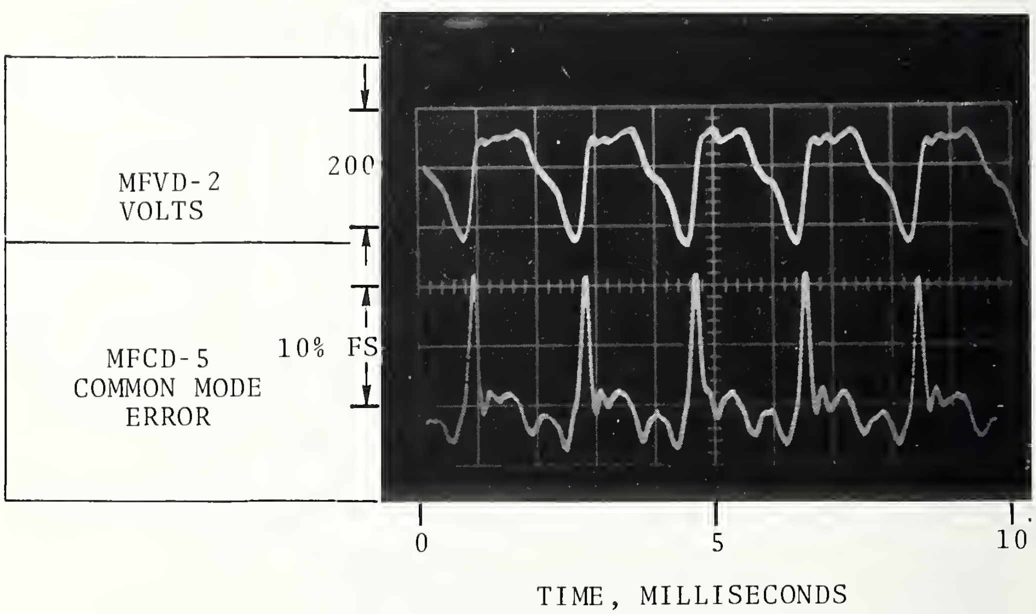
tests at TSC. While the CMRR exceeds 140 dB at DC, it degrades with increasing frequency.

For example, a dynamic common mode voltage of 50 volts peak occurring at approximately 110 Hz (CMRR = -60 dB) would cause an output signal of 0.050 volts peak at the same frequency. With an output full scale range of 5.0 volts, the 0.050 volt signal represents an error of 1 percent FS.

The current shunt system was designed to measure DC or slowly varying currents with shunts inserted in relatively constant potential circuits. Short duration transients were expected at infrequent intervals. During this test at TTC however, the voltage generated by DOT-001 was characterized by 200 volt negative spikes occurring at a 525 Hz repetition rate. These spikes did induce error signals on the current shunt signals MFCD-2 through MFCD-5. The error signals are all of the same polarity in spite of the various polarity hook-ups of each shunt. This substantiates the common mode voltage as the error source. In addition, MFCD-1, the ground input channel, did not exhibit the CMV errors.

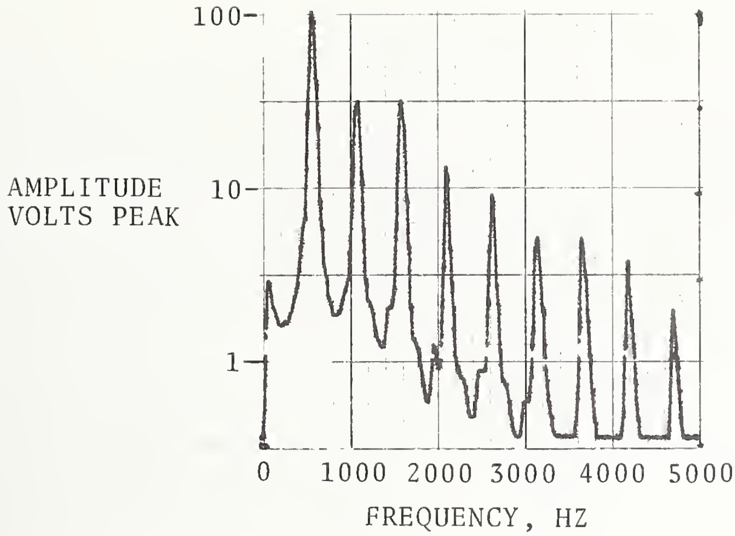
Figure C-21 is an oscilloscope photograph of the motor field voltage with respect to ground and the field current common mode error as measured by MFCD-5. The tape speed was 15 ips with a resulting signal bandwidth of 5 kHz.

The data from Figure C-21 was also used to generate the frequency spectra shown in Figure C-22. The CMRR at each discrete frequency displays good correlation at the laboratory data.

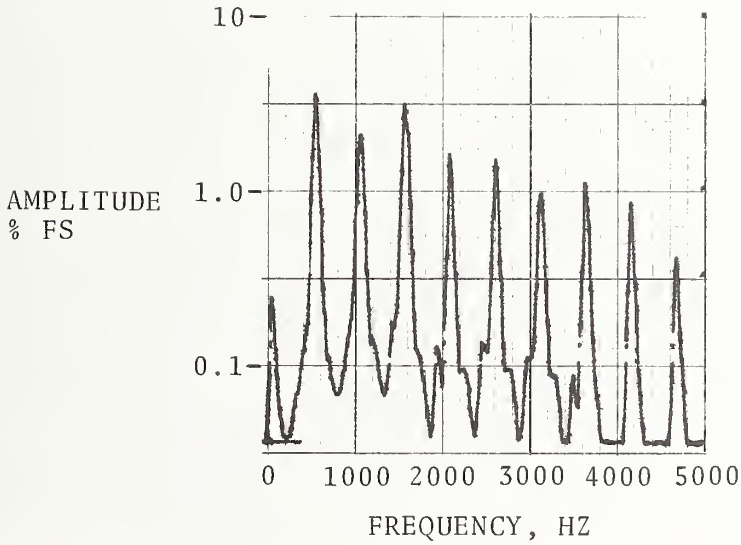


- RUN 200/7
- COUNTERCLOCKWISE
- CONSTANT SPEED
- SIGNAL BANDWIDTH - 5 KHz

FIGURE C-21. CURRENT SHUNT SIGNAL MFCD-5 COMMON MODE ERROR OSCILLOSCOPE TRACE



COMMON MODE FIELD VOLTAGE, MFVD-2



COMMON MODE FIELD CURRENT ERROR, MFCD-5

- RUN 200/7
- CONSTANT SPEED
- COUNTERCLOCKWISE
- SIGNAL BANDWIDTH - 5 KHz

FIGURE C-22. CURRENT SHUNT COMMON MODE ERROR AND COMMON MODE VOLTAGE FREQUENCY SPECTRA

To illustrate, the dynamic common mode voltage component at 1040 Hz is 32 volts peak. The current shunt error signal at that frequency is 2 percent FS (.100 volt peak). The ratio of this error voltage to the common mode voltage is -50 dB. Referring to Figure C-20, the lab test derived CMRR indicates a -49 dB value at 1040 Hz.

It is again emphasized that under normal TTC operating conditions, the error producing CM voltages would not be present.

REDUNDANT DATA COMPARISON

Figure C-23 is a chart recording of the three redundant current signals and their electrical summation signals. (MFCD-4) - (MFCD-2) has a DC offset of + .5% FS while the gain difference is less than .25% FS. (MFCD-2) + (MFCD-3) has a DC offset of .2% FS with a gain difference of less than 0.5% FS.

The increased noise observed on the latter trace is probably caused by the additive effects of the common mode error previously discussed. In addition, MFCD-3 and MFCD-4 were recorded on different tape head stacks with any playback misalignment causing channel time delays. Summations of out-of phase signals could induce the noise observed on this track.

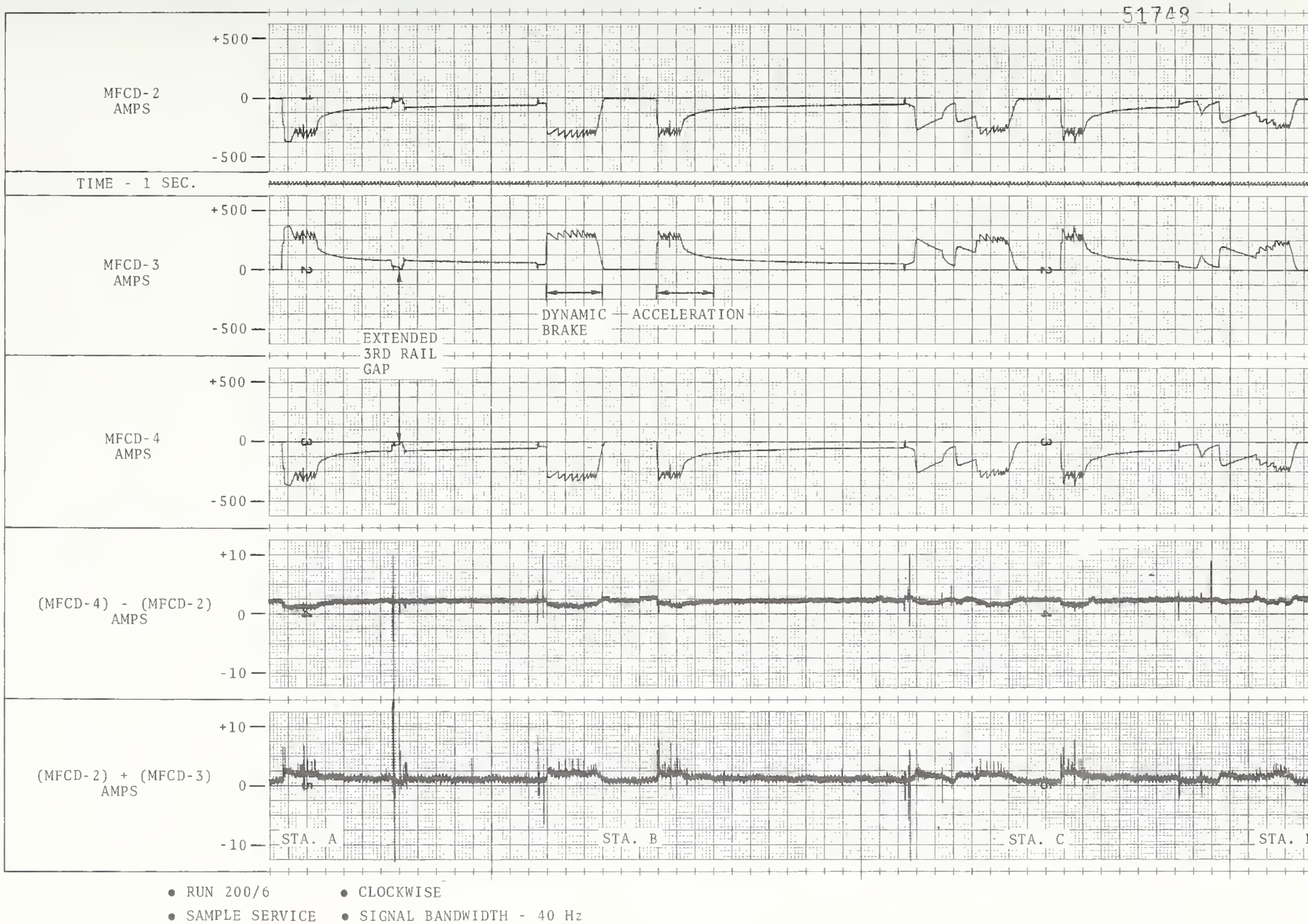


FIGURE C-23. CURRENT SHUNT REDUNDANT SIGNAL CHART RECORD

TEST SET	**TEST TITLE:** Current Probe Evaluation **TEST SET NO.:** R42-I-5202-TT

TEST OBJECTIVE: To evaluate the use of magneto-resistive current probes by comparison to identical signals from current shunts.

TEST DESCRIPTION: Both current shunts w/isolation amplifiers and current probes were installed on test vehicle. Line and #1 truck currents were determined with redundant measurements from each system.

Accuracy of the current probes was determined when installed after a lab calibration. Effectiveness of installation procedures to provide accurate data without an "in-situ" calibration was evaluated.

STATUS: Sufficient data was collected and analyzed to evaluate the current probes. The probes are highly sensitive to the magnetic fields generated by nearby current carrying conductors. As a result extreme care must be taken to insure adequate installation.

FIGURE C-24. CURRENT PROBE EVALUATION TEST SUMMARY

C2. CURRENT PROBE EVALUATION

C2.1 TEST SUMMARY

See Figure C-24 preceding.

C2.2 PROCEDURE

The measurement of electrical current is required to determine the energy consumption of a vehicle. In addition, the operation of a vehicle control system can be evaluated by observing variations in current as a function of time. In this test, clamp-on current probes were evaluated as current measurement devices.

The probes contain a magneto-resistive bridge circuit that senses the magnetic field generated by the current flowing through a conductor. The primary advantage of the clamp-on probe is that no electrical modifications to the vehicle circuits are required. (The shunt system must be connected in series with vehicle circuits.) Under ideal conditions, the probe installation would be easily completed. Laboratory tests indicated, however, that the probes are susceptible to magnetic flux from any source, including nearby current carrying conductors, motors, and even the earth's magnetic field.

All of the probes used on this test were calibrated using a 60-turn test coil with a shunt in series with the coil. By supplying 5 amps to the coil, a magnetic field equivalent to 300 amps flowing in a single conductor was simulated. Each probe was adjusted to within ± 1.5 percent FS.

A simplified discussion of the vehicle motor connections is given in Paragraph C1.2. The measurements performed on this test are shown schematically in Figure C-25. Nomenclature corresponds to GVTP standard outputs.

MFCD - Motor Field Current, dc

MACD - Motor Armature Current, dc

LCD - Line Current, dc

LVD - Line Voltage, dc

The purpose of each measurement is as follows:

MFCD-1 Shunt mounted in motor field circuit for reference

MFCD-2 Mid car mounted probe

MFCD-3 Truck mounted probe

$$(MFCD\text{-}1) = (MFCD\text{-}2) = -(MFCD\text{-}3)$$

MACD-1 Shunt mounted in motor armature circuit for reference

MACD-2 Mid car mounted probe

MACD-3 Truck Mounted probe

$$MACD\text{-}1 = MACD\text{-}2 = -(MACD\text{-}3)$$

LCD-1 Shunt mounted in line current circuit in knife switch box

LCD-2 Truck mounted probe on shoe lead of number 2 truck

LCD-3 Truck mounted probe on shoe lead of number 1 truck

$$LCD\text{-}1 = (LCD\text{-}2) + (LCD\text{-}3)$$

LVD-1 Voltage divider connected at knife switch box.

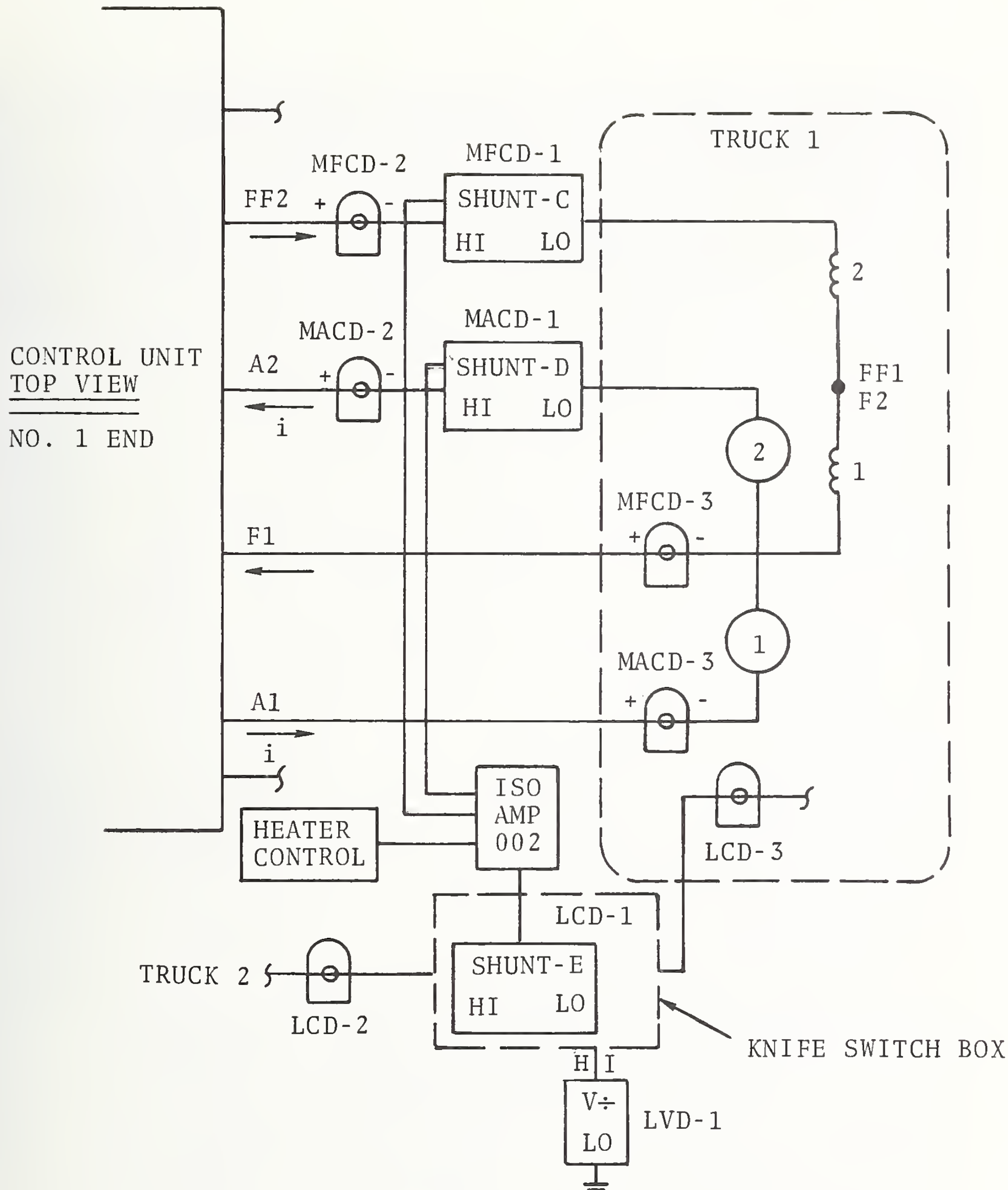


FIGURE C-25. SCHEMATIC OF CURRENT PROBE WITH CURRENT SHUNT TEST INSTALLATION

A photograph of the mid-car probes and shunts is given in Figure C-26. Note the nearby conduits carrying line and motor currents of significant magnitudes. These sensors are located within two feet of the vehicle control unit. Figure C-27 shows the truck mounted probes. The LCD-1 shunt installed in the knife switch box is shown in Figure C-28. For this installation, the knife contact bar was removed. Contact blades were fabricated for the shunt with the blades inserted between the knife spring contacts to complete the circuit.

A jumper, J1, was also added to simulate the knife bar to provide power for the vehicle auxiliary equipment.

The test track configuration for this test was the ACT I Synthetic Transit Route described in Paragraph C1.2.

C2.3 INSTRUMENTATION

Figure C-29 is a block diagram of the instrumentation system used for this test.

Sensors

Type	Mfgr.	Model No.	Qty
Current Probes	Amer. Aero.	909-500	4
		909-1000	2
Current Shunts	Janco	8406-500	2
		8406-1000	1
ALD	Kaman	KD 1106-10C	1
Voltage Divider	TSC	DVD-1	1

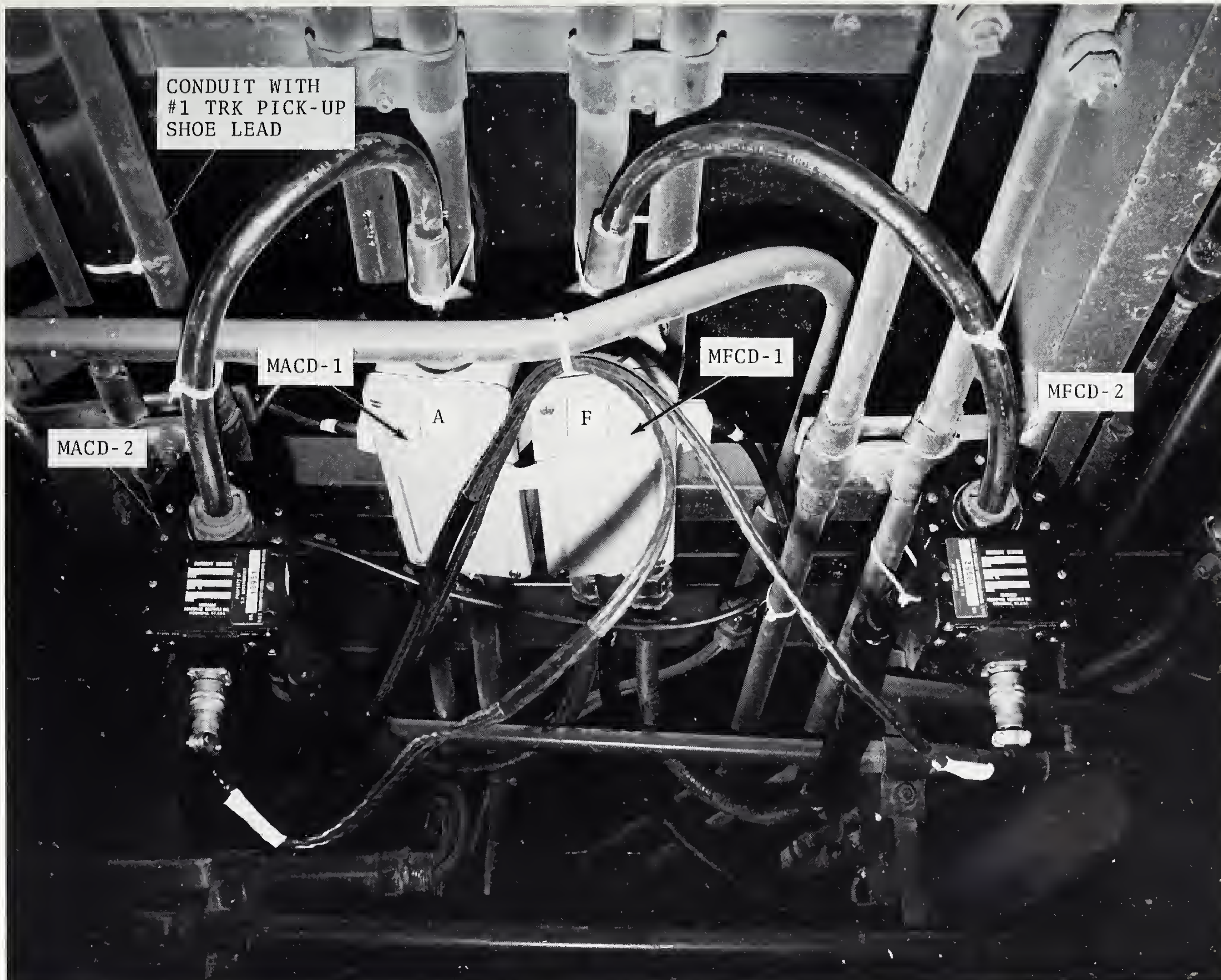


FIGURE C-26. CURRENT PROBE AND SHUNT INSTALLATION, MID-CAR LOCATION

FIGURE C-27. CURRENT PROBE INSTALLATION TRUCK LOCATION

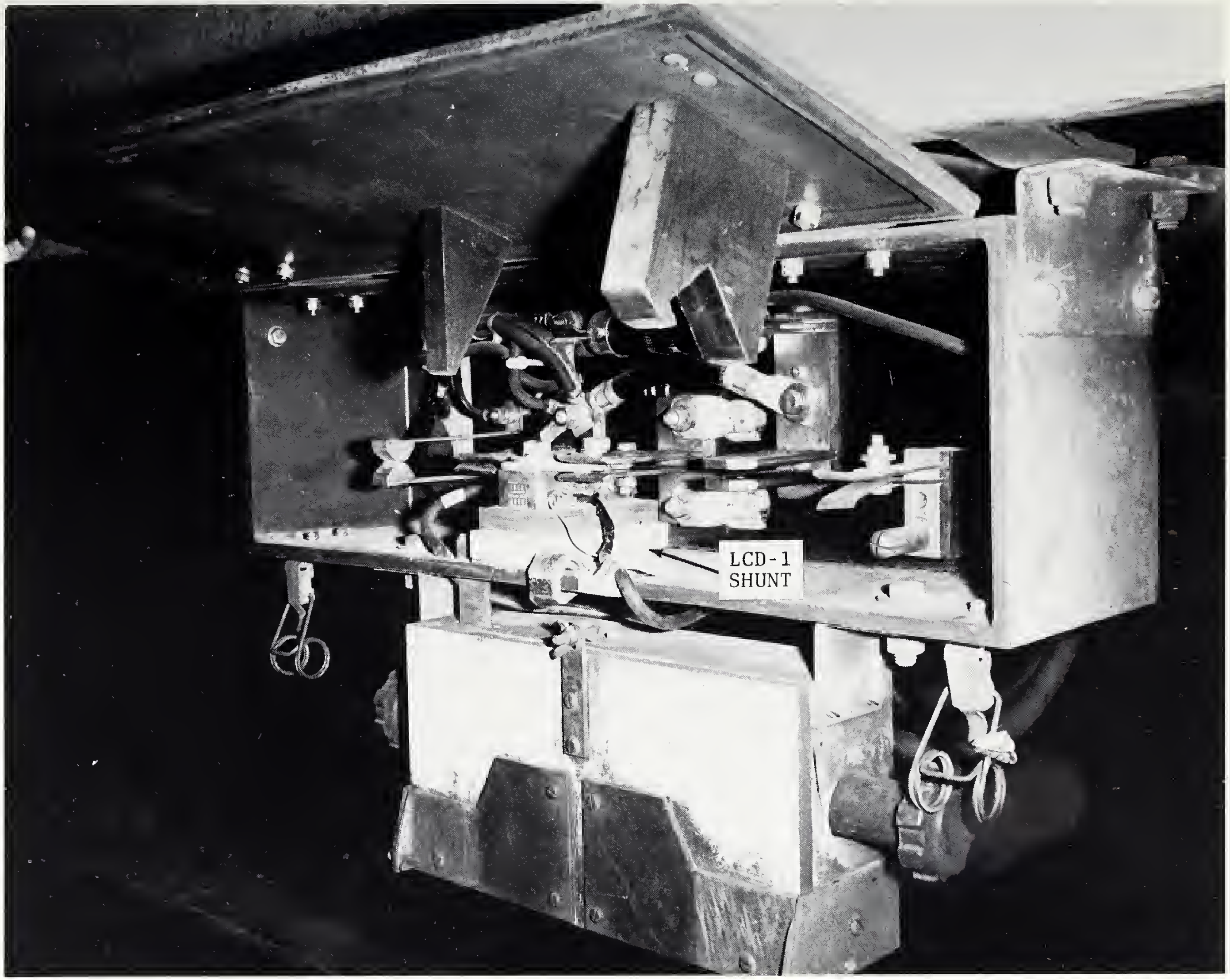


FIGURE C-28. LINE CURRENT SHUNT INSTALLATION, KNIFE SWITCH BOX

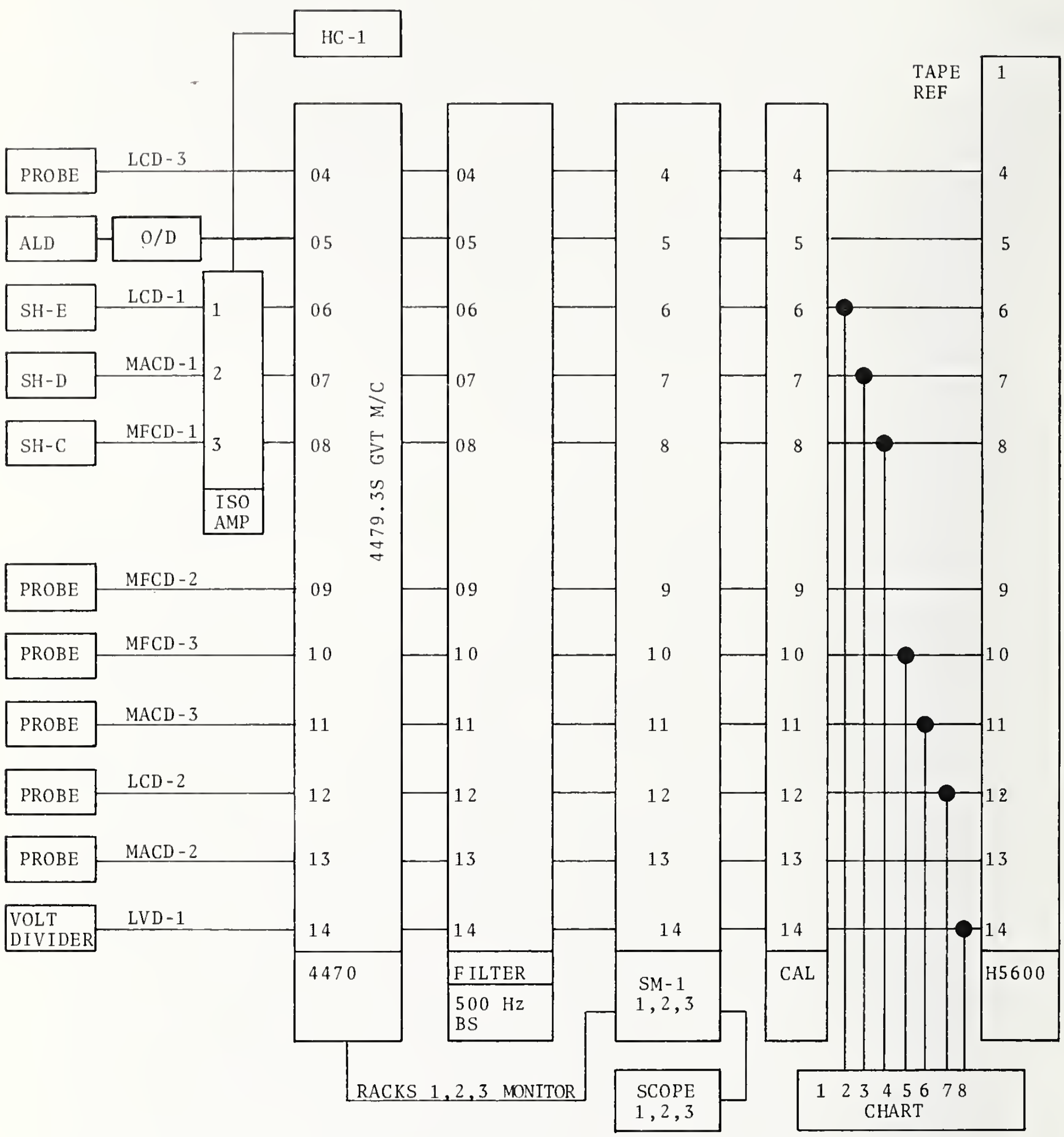


FIGURE C-29. CURRENT PROBE WITH CURRENT SHUNT TEST EQUIPMENT, BLOCK DIAGRAM

Preconditioner			
Isolation Amplifier	TSC	ISO-1	1
Oscillator/Demodulator (ALD)	Kaman	KD 2300-12CU	1
Control/Interface			
Heater Control Chassis	TSC	HC-1	1
Mode Card			
GVT Type	TSC	4479.3S	10
ALD	Endevco	4475.1 w/TSC Mod K	1

All other items shown on the block diagram are discussed in Appendix A.

C2.4 PROCEDURES

I PRELIMINARY

A. Install test equipment per Figure C-25 schematic and Figure C-29 block diagram.

B. Complete log documentation sheets.

C. Verify signal routing.

D. Verify proper mounting of current probes including:

1. Non-magnetic mounting hardware.
2. 12-inch linear conductor.
3. Proper orientation of sensing element with respect to adjacent conductors.
4. Conductor centered in yoke.

II TEST

A. Proceed to test loop.

B. Verify system operation.

C. Calibrate tape unit:

1 minute @ 0.0 volts,
1 minute @ 5.0 volts.

D. Power rail.

E. Verify heater warmup.

F. Observe zero signal levels on scope.

G. Operate vehicle on command of Chief Test Engineer.

H. Debug and document all problems on each channel.

I. Operate vehicle in a sample service mode described as follows:

1. Use synthetic transit route CW beginning at station A.

2. Calibrate recorder at station stops A, E, J, O.

3. Zero signal conditioners prior to run.

C2.5 PRELIMINARY DATA ANALYSIS

The data selected for detailed analysis was collected on Run 200/12. This run was a clockwise sample service run using the synthetic transit route. The run lasted 29 minutes.

Zero Signal Drift

At each station stop, the current flowing through the

motor fields and armatures is reduced to zero. The zero signal levels were monitored on a chart recorder and measured with a digital voltmeter. The maximum drifts were:

MFCD-2	-1.1% FS
MFCD-3	+0.5% FS
MACD-2	-0.7% FS
MACD-3	+0.3% FS

The cause of the drifts is undetermined but laboratory tests indicate they were not temperature induced.

Redundant Data Comparison

Both current shunts and current probes were used to measure the motor field, armature, and line currents. The probe signals were electrically summed with the shunt signals and the difference displayed on a chart recording. Most of the error signals can be traced to interference from adjacent current carrying conductors.

Line Current

Figure C-30 is a chart recording of the signals from the three line current sensors. An electrical summation of the signals is also displayed along with the line voltage. As the contact shoes slide on the third rail, the current demanded by the vehicle is randomly supplied by one or both pick-up shoes. LCD-2 and LCD-3 exhibit this current collection crossover. When the vehicle passes a gap in the third rail, only one shoe at a time makes contact. A third rail gap is also noted on Figure C-30.

The summation of the two shoe current probe signals minus

- RUN 200/12
- SAMPLE SERVICE
- CLOCKWISE
- SIGNAL BANDWIDTH - 40 Hz

FIGURE C-30. CURRENT PROBE AND SHUNT LINE CURRENT SIGNALS CHART RECORD

the knife switch shunt signal is displayed on a ± 10 percent FS range. Under ideal conditions, this signal would be zero. The 5 percent error appears to be a scale factor problem with probe LCD-3.

Motor Field Current

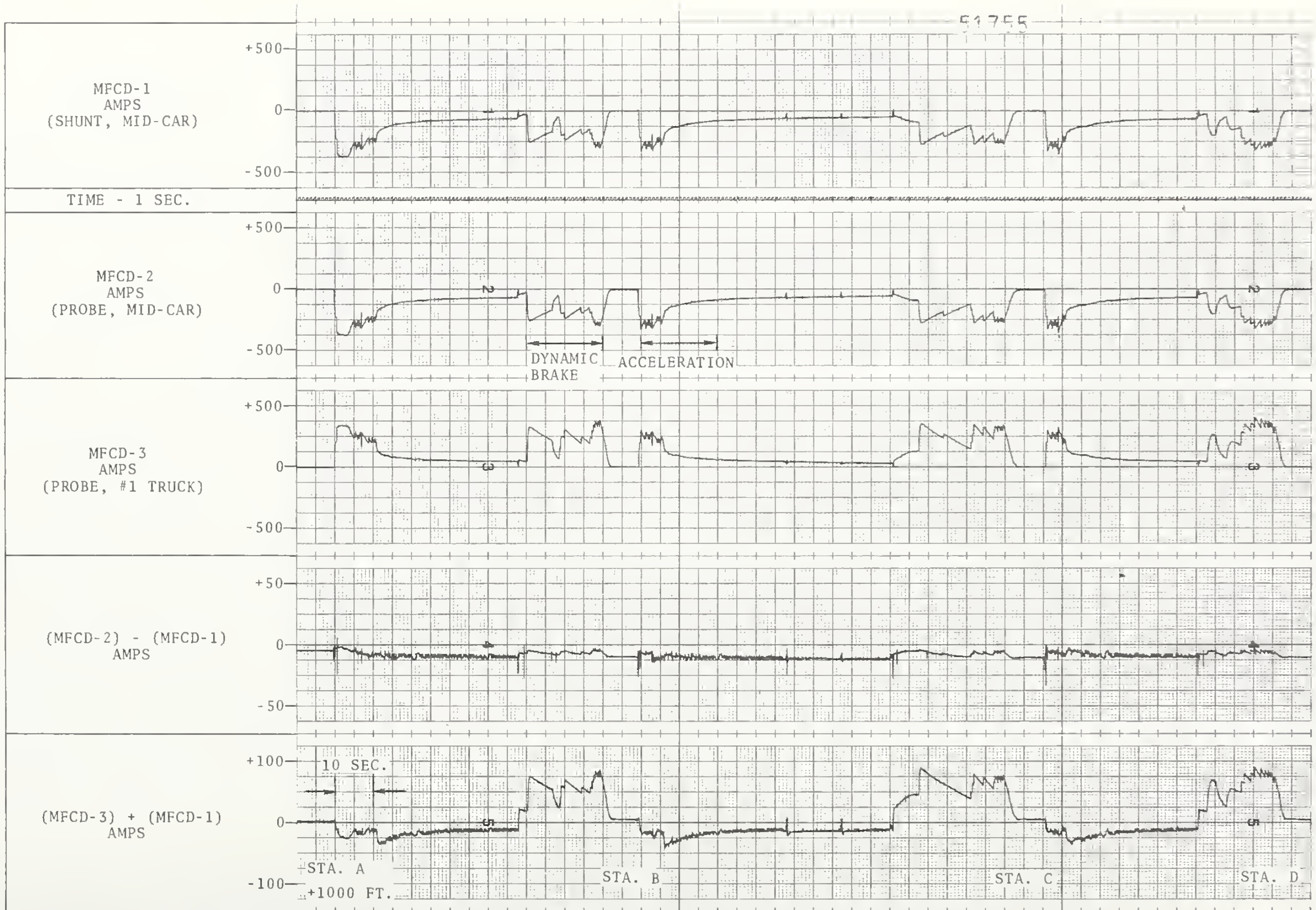
Figure C-31 displays data from the field current shunt, mid-car probe and truck probe. Each probe signal was individually summed with the shunt signal and also displayed on the chart. The best correlation between any shunt and probe data was with MFCD-1 and MFCD-2. Errors of less than 2.5 percent FS were observed. From the probe installation photograph Figure C-26, it is noted that the probe was relatively distant from other high current carrying conductors. Errors from the truck-mounted probe MFCD-3, however, exceeded 15 percent FS during dynamic brake applications.

The current probe installation photograph, Figure C-27, shows the proximity of motor and shoe leads, motor housings, and metal structures. All of these items produce magnetic fields and field distortions with resultant errors.

Motor Armature Current

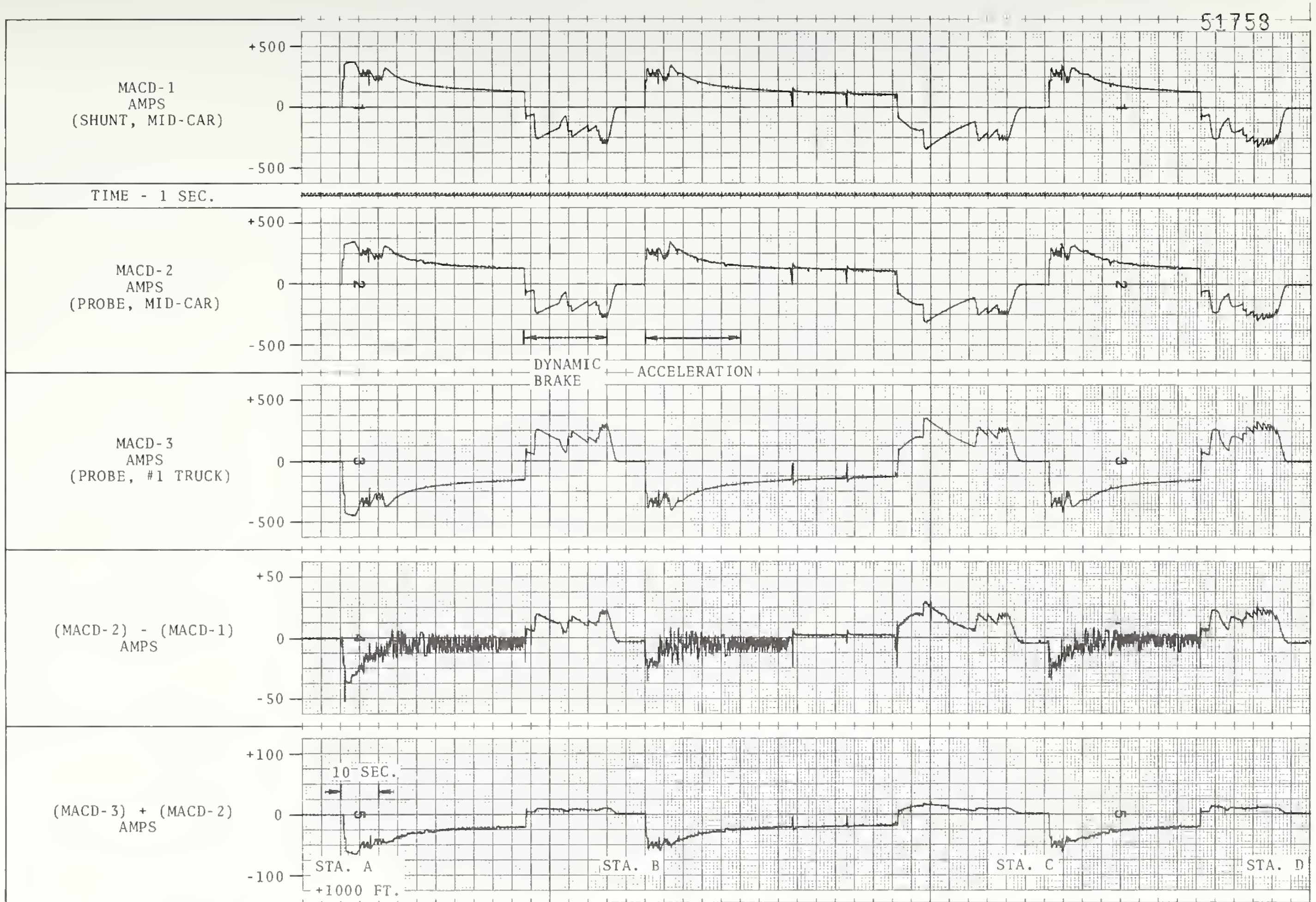
Figure C-32 is a chart recording displaying the motor armature currents from the three sensors and their summation signals. Again, the truck mounted probes exhibit large errors exceeding 10 percent FS. Errors on the mid-car probe are generally 5 percent FS.

Figure C-26, shows that the probe is mounted directly below the conduit carrying the number one truck pick-up shoe lead. Figure C-33 displays the mid-car probe error summation and the shoe lead current signal. The interference is especially evident when



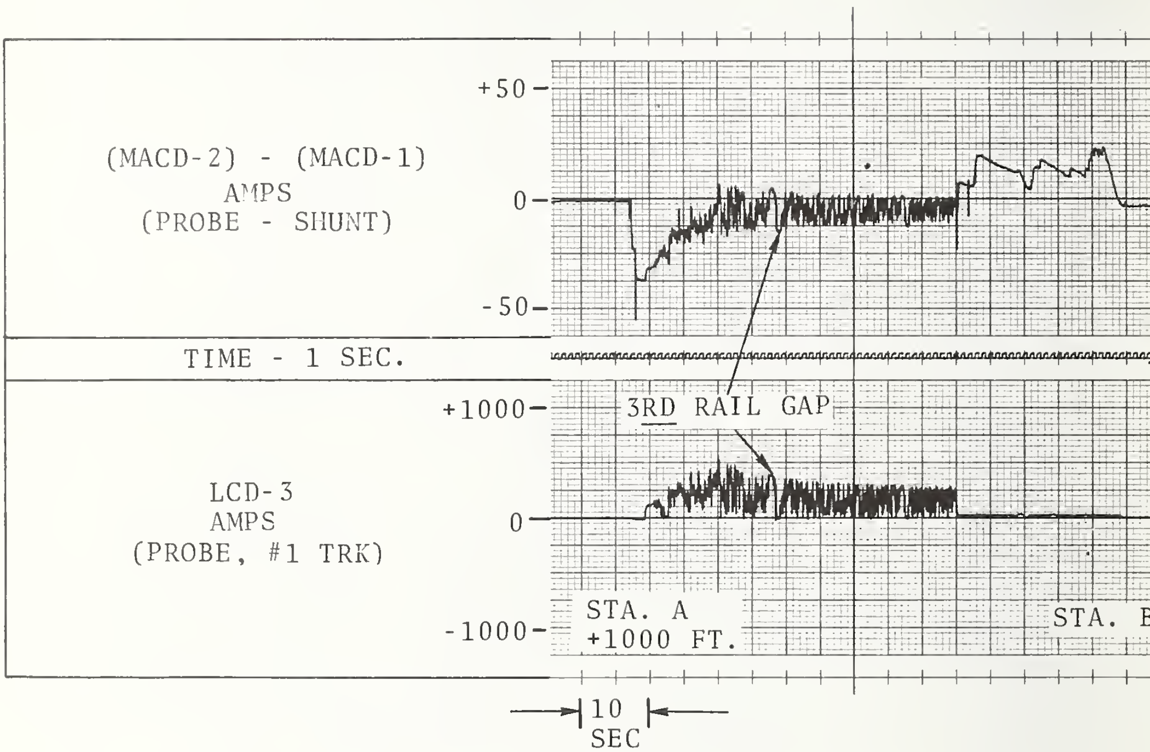
• RUN 200/12
• SAMPLE SERVICE
• CLOCKWISE
• SIGNAL BANDWIDTH - 40 Hz

FIGURE C-31. CURRENT PROBE AND SHUNT MOTOR FIELD CURRENT SIGNALS CHART RECORD



- RUN 200/12
- SAMPLE SERVICE
- CLOCKWISE
- SIGNAL BANDWIDTH - 40 Hz

FIGURE C-32. CURRENT PROBE AND SHUNT MOTOR ARMATURE CURRENT SIGNALS CHART RECORD



- RUN 200/12
- SAMPLE SERVICE
- CLOCKWISE
- SIGNAL BANDWIDTH - 40 Hz

FIGURE C-33. CURRENT PROBE ERROR SIGNAL FROM NEARBY LINE CURRENT CONDUCTOR, CHART RECORD

the vehicle crosses over a rail gap. A 400 amp change in line current induces a 20 amp error in the armature current measurement.

Conclusions

From the photograph, Figure C-27, it is apparent that proper mounting of the current probes was not achieved, except in the case of the mid-car field current probe. If these probes are to be used with GVTP specified accuracy, the mounting constraints given in the test procedures must be strictly followed. If the vehicle configuration does not permit proper installation, the current shunt system should be used.

APPENDIX D

PRESSURE, TEMPERATURE, STRAIN, AND DISPLACEMENT SYSTEMS

The following test sets are discussed in this appendix.

Test Category	Test Set No.	Test Title	Page
Pressure, Temperature, and Strain	R42-I-5301-TT	Pressure, Temperature and Strain Systems Evaluation	D-3
Displacement	R42-I-5302-TT	Displacement Systems Evaluation	D-24

TEST SET	TEST TITLE: Pressure, Temperature, and Strain System Evaluation TEST SET NO.: R42-I-5301-TT

TEST OBJECTIVE: To determine the operational characteristics of the pressure, temperature and strain measurement systems.

TEST DESCRIPTION: The test vehicle was operated under simulated GVT procedures including accel/decel and sample service. Parameters determined include:

1. Zero signal drift
2. Electrical Noise Pickup
3. Redundant Data Comparison

STATUS: Sufficient data was collected to evaluate the pressure, temperature, and strain systems. No equipment malfunctions were experienced.

FIGURE D-1. PRESSURE TEMPERATURE STRAIN SYSTEM EVALUATION TEST SUMMARY

D1. PRESSURE, TEMPERATURE, AND STRAIN SYSTEMS EVALUATION

D1.1 TEST SUMMARY

See Figure D-1 preceding.

D1.2 PROCEDURE

The pressure and temperature measurements are specified in detail in the GVTP. Brake pressure measurements can be used to evaluate the vehicle control system as well as motorman expertise. The temperature measurements provide data on equipment environments that could be used to indicate equipment malfunctions (worn bearings, rubbing brake shoe, etc.).

Strain measurements are not specified in detail. The location and accuracy of these systems must be optimized for each individual test vehicle. Previous tests on the state-of-the-art-car utilized strain measurements to determine if dynamic strain levels existed within the truck assembly that would decrease the useful life of its components.

All three measurement systems operated on a variable resistance principle. The resistance of a strain gage varies as a function of strain while temperature gage resistance varies as a function of temperature. The pressure sensor contains a strain gage assembly.

Two pressure sensors were mounted in series with the brake cylinder air on the number one truck. Under ideal conditions, the sensors output signals would be identical. Figure D-2 shows the sensor installation.

FIGURE D-2. BRAKE PRESSURE SENSOR TEST INSTALLATION, NO. 1 TRUCK

Two temperature gages were bonded to the top of the heat shield that covered the motor current limiting resistor grid. The gages were installed as shown in Figure D-3. A third constant temperature signal was generated by stable fixed resistors simulating a temperature gage. Because of the proximity of the active gages, and the thickness of the shield (approximately .060 inch), close agreement between readings would be expected.

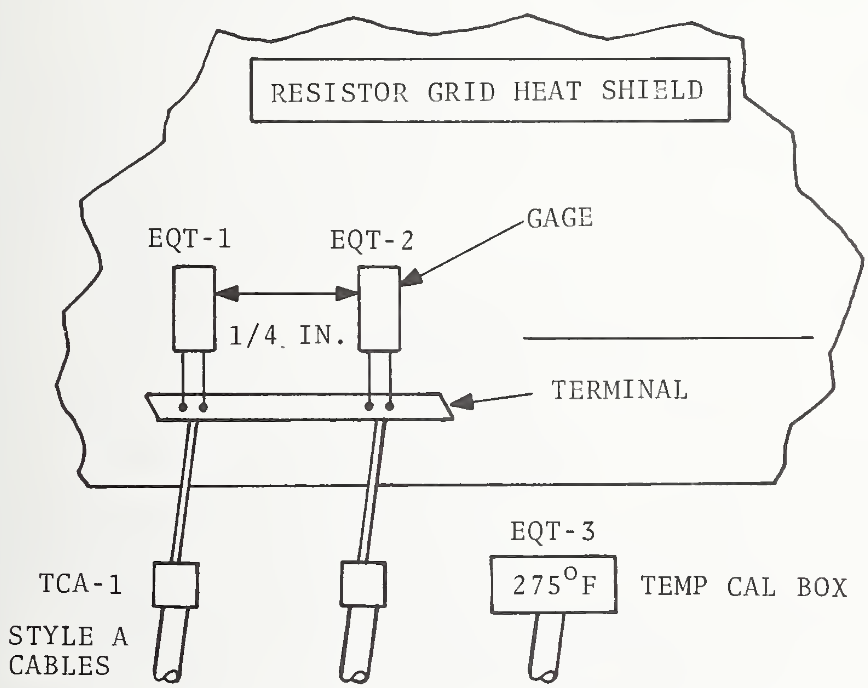


FIGURE D-3. SCHEMATIC OF TEMPERATURE GAGE TEST INSTALLATION, RESISTOR GRID HEAT SHIELD

A four active arm strain gage bridge was mounted on the Track Geometry Measurement System beam bracket. The bracket attaches to the journal box with a modified plug and is supported by leveling screws bearing on the contact shoe beam housing. The gages were installed next to the lower leveling screw and

covered with a waterproof coating. The installation is shown in Figure D-4. Two of the gages were mounted on the underside of the bracket. To determine noise pick-up, a constant strain signal was generated by a commercial strain gage calibrator using fixed resistors. The calibrator was located inside the vehicle but the cable was routed alongside the other strain gage cable.

The sensor nomenclature refers to the GVTP standard outputs.

BCP	Brake Cylinder Pressure
EQT	Equipment Temperature
STPS	Structural Test Parameter-Strain

The purpose of each measurement is listed below:

Pressure	BCP-1 BCP-2	Redundant pressure signals
Temperature	EQT-1 EQT-2	Redundant temperature signals
	EQT-3	Simulated constant temperature signal to determine drift and noise
Strain	STPS-1	Bracket strain signal
	STPS-2	Simulated constant strain signal to determine drift and noise

The synthetic transit route described in Section C1.2 was utilized for all test runs.

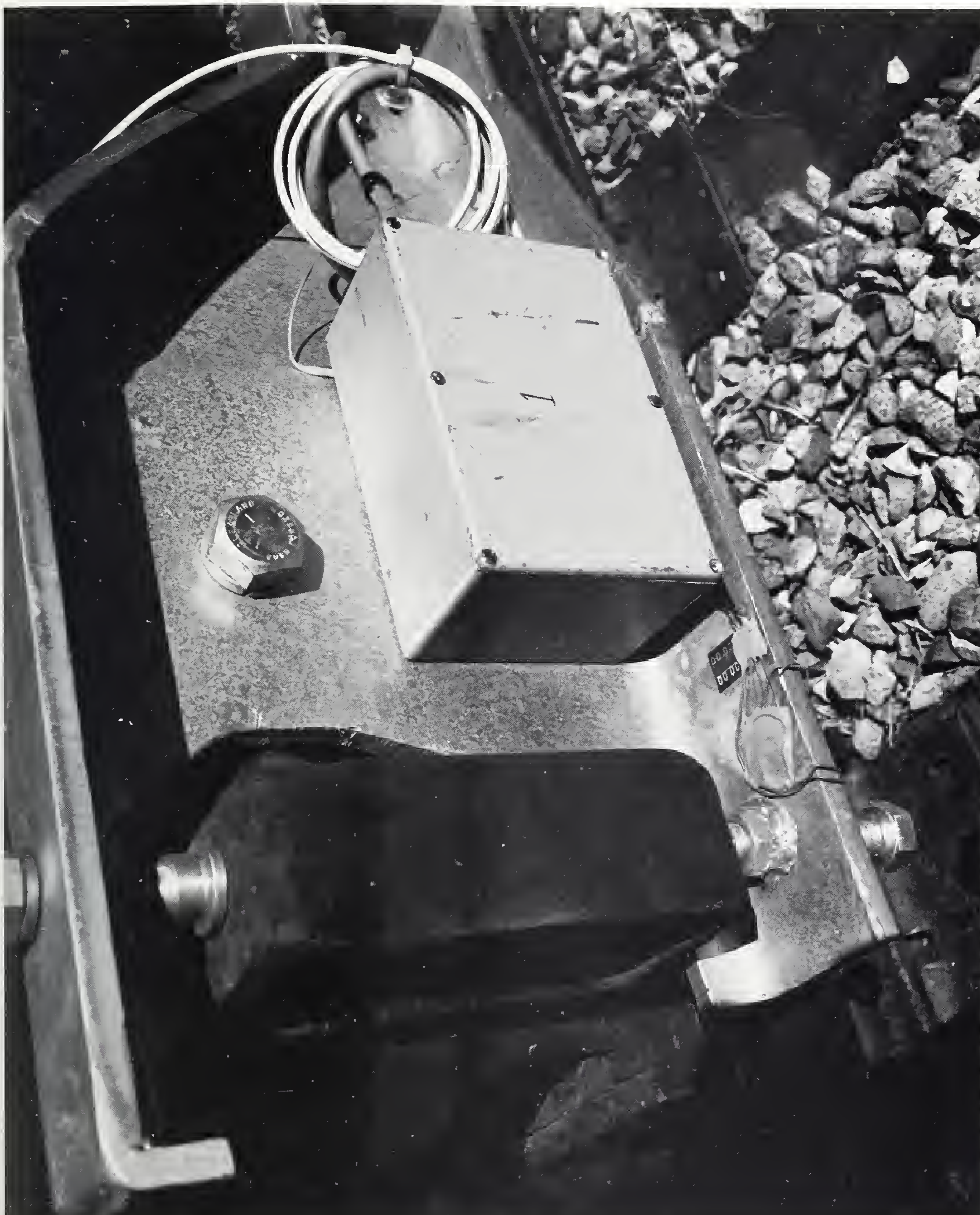


FIGURE D-4. STRAIN GAGE TEST INSTALLATION, NO. 2 TRUCK

D1.3 INSTRUMENTATION

A block diagram of the pressure, temperature, and strain measurement systems for this test is shown in Figure D-5.

Sensors

Type	Mfgr.	Model No.	Qty
ALD	Kaman	KD1106-10C	1
Temperature Gages 50 ohm at 75°	Micro-Measurements	WTG-50BP	2
Pressure Sensor 200 psig Range	BLH	Type DHF	2
Strain Gage 350 ohm	BLH	Type FAE-12A-3559L	4
Strain Gage Calibrator	BLH	Model 625	1

Preconditioner

Type	Mfgr.	Model No.	Qty
Oscillator/Demodulator	Kaman	KD2300-12CU	1
Temperature Connector Assembly	TSC	TCA-1	2
Strain Connector Assembly	TSC	SCA-1	2

A photograph of a temperature gage, terminal, and connector is shown in Figure D-6.

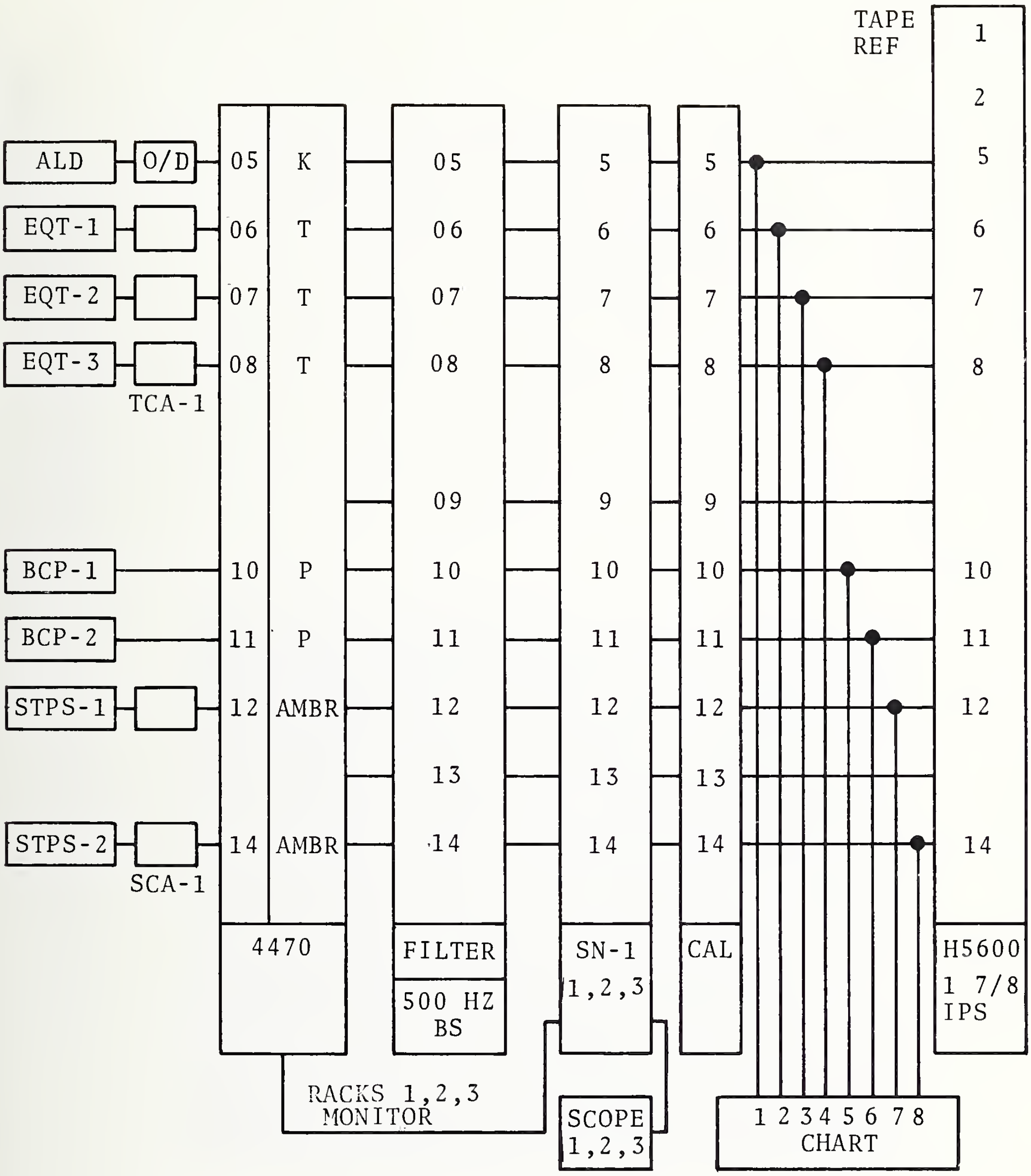


FIGURE D-5. PRESSURE, TEMPERATURE AND STRAIN TEST EQUIPMENT, BLOCK DIAGRAM

Mode Card

ALD	Endevco	4475.1 w/TSC Mod K	1
Temperature	Endevco	4476.2AM3 w/TSC Mod T	3
Pressure	Endevco	4476.2AM3 w/TSC Mod P	2
Strain	Endevco	4476.2AM3	2

All other items in the block diagram are discussed in Appendix A.

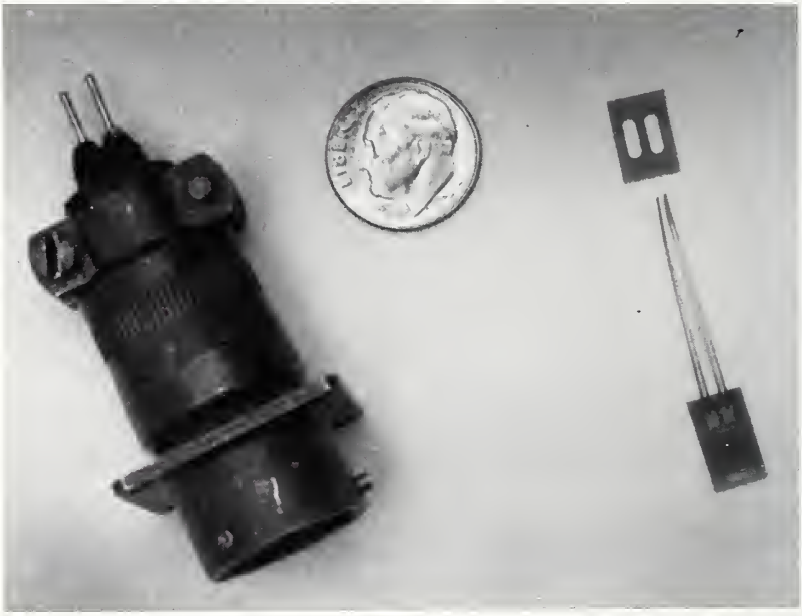


FIGURE D-6. TEMPERATURE CONNECTOR ASSEMBLY, GAGE, AND SOLDER TERMINAL

D1.4 PROCEDURES

I PRELIMINARY

A. Install test equipment as shown in Figures D-2 through D-5.

B. Verify signal routing by simulation.

C. Complete log documentation sheets.

II TEST

A. Proceed to test loop.

B. Verify system operation.

C. Calibrate tape unit:

1 minute @ 0.0 volts,
1 minute @ 5.0 volts.

D. Power rail.

E. Observe zero signal levels on scope.

F. Operate vehicle on command of Chief Test Engineer.

G. Debug and document all problems on each channel.

H. Operate vehicle in a sample service mode described below:

1. Use synthetic transit route CW beginning at Station A.

2. Calibrate recorder at station stops A, E, J, O.

3. Zero signal conditioners prior to run.

D1.5 PRELIMINARY DATA ANALYSIS

The data selected for detailed analysis was collected on run 300/2. This run was a clockwise, sample service run using the synthetic transit route. The run lasted 27 minutes. The discussion of the data analysis is divided into pressure, temperature, and strain data. All data was recorded at 1 7/8 ips with a maximum filter bandwidth of 500 Hz.

D1.5.1 Pressure

Noise Pick-up

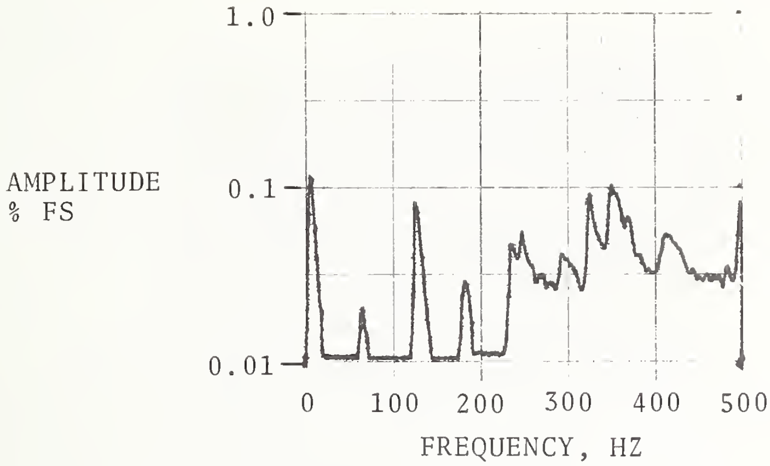
Frequency spectra were generated for the tape channel noise during a zero volt calibration and for the BCP-1 signal during a constant speed portion of the test run. The spectra are shown in Figure D-7. There is no appreciable difference in the plots indicating negligible noise pick-up in the sensor system.

Redundant Data Comparison

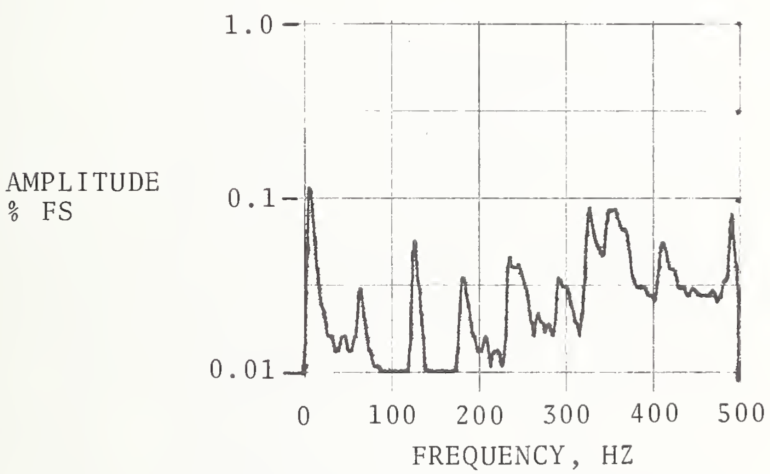
Figure D-8 is a chart recording of the beginning of run 300/2. Both brake cylinder pressure signals are displayed as is the difference signal. The maximum difference signal throughout the run was ±0.25% FS. BCP-1 exhibits a slightly higher scale factor than BCP-2.

D1.5.2 Temperature

Each of the three temperature channels was calibrated for 500°F full scale. Calibration is accomplished by substituting fixed resistors simulating 0°, 75° and 250°F and adjusting amplifier gain.



TAPE NOISE AT ZERO VOLT CAL



SIGNAL NOISE AT CONSTANT VEHICLE SPEED

NOTE: 1.0% FS OF THE TAPE RECORDER OUTPUT CORRESPONDS TO A 10 MV PEAK DISCRETE FREQUENCY SINE WAVE USED TO CALIBRATE THE SPECTRUM ANALYZER.

- RUN 300/2
- CLOCKWISE
- CONSTANT SPEED
- 500 Hz RANGE

FIGURE D-7. BRAKE PRESSURE NOISE SIGNAL BCP-1 FREQUENCY SPECTRA

- RUN 300/2
- SAMPLE SERVICE
- CLOCKWISE
- SIGNAL BANDWIDTH - 40 Hz

FIGURE D-8. BRAKE PRESSURE REDUNDANT SIGNAL CHART RECORD

Zero Signal Drift

EQT-3 was a fixed resistor simulating a 75°F temperature. Monitoring this signal during tape playback indicated a +1.0°F drift occurred during the test run.

Noise Pick-up

The frequency spectra shown in Figure D-9 indicate no significant difference between the tape noise and the recorded temperature system noise. It is concluded that noise pick-up of the temperature system is negligible.

Redundant Data Comparison

EQT-1 and EQT-2 temperature gages were mounted to minimize their temperature difference. Figure D-10 is a chart recording displaying EQT-1 and the difference (EQT-2) - (EQT-1). The constant temperature reference EQT-3 is also shown. The maximum difference signal was ±0.25% FS. The EQT-1 range during the entire 300/2 run was from 70° to 125°F.

D1.5.3 Strain

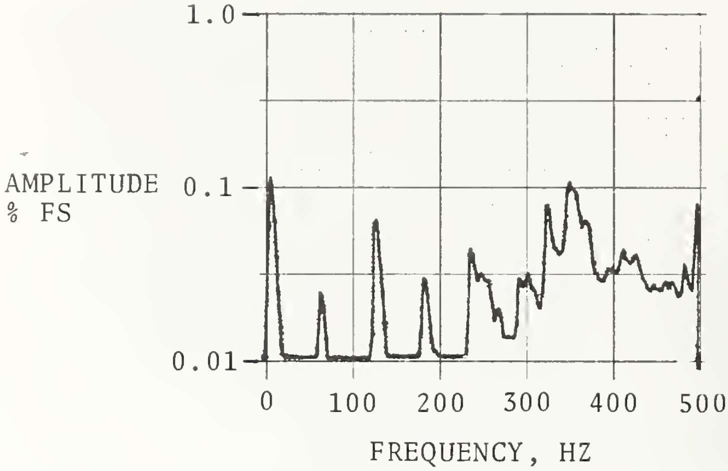
Each strain system utilized an excitation voltage of 10 vdc with an amplifier gain of 1000. The equivalent full scale strain was ±250 micro inches/inch.

Zero Signal Drift

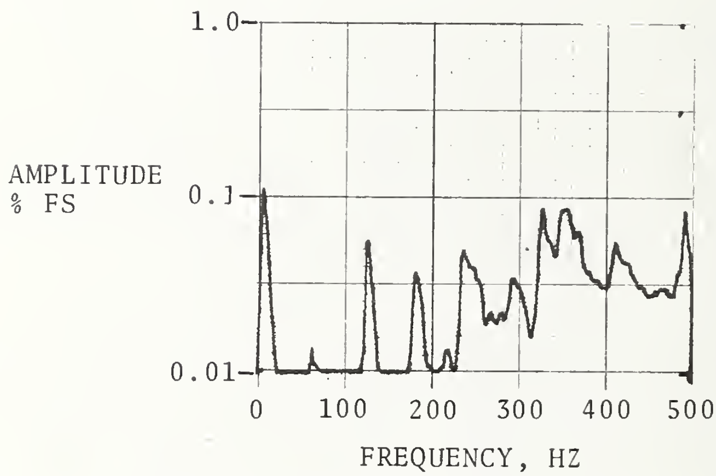
STPS-1 was a commercial strain gage calibrator that generated a zero strain signal. The maximum drift of this signal was 0.1% FS.

Noise Pick-up

Figure D-11 displays frequency spectra of the STPS-2 tape



TAPE NOISE AT ZERO VOLT CAL

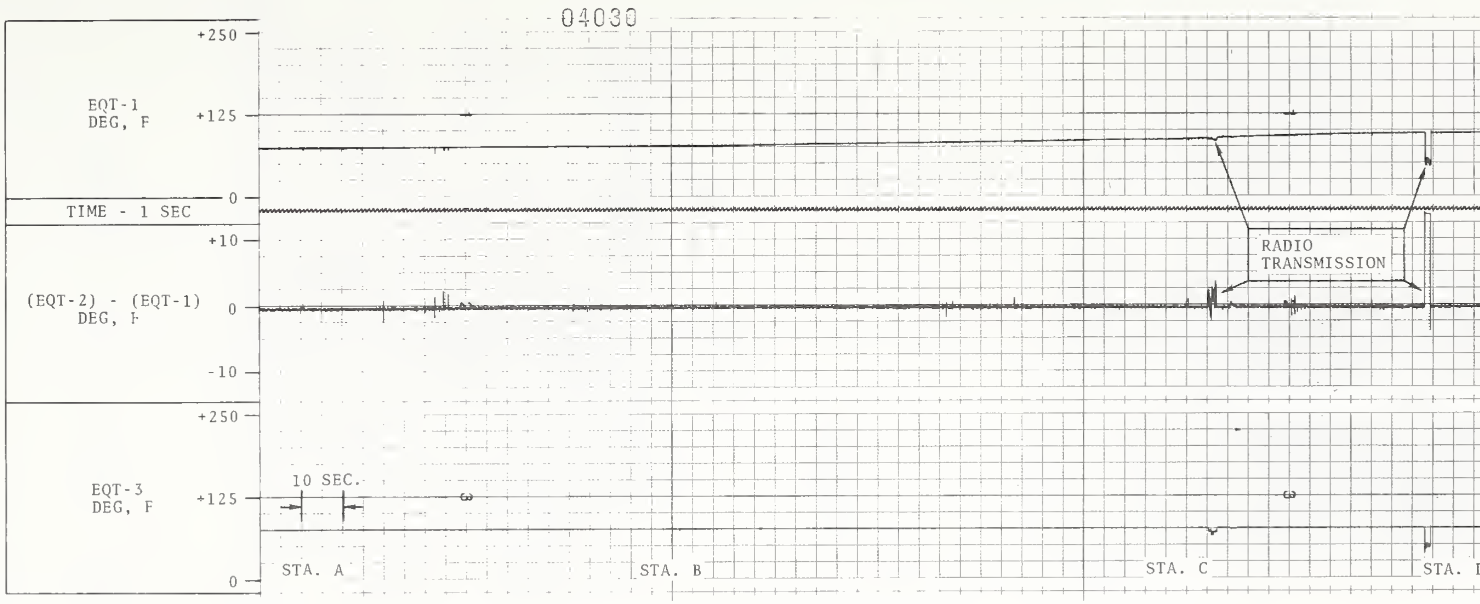


EQT-3 NOISE AT CONSTANT VEHICLE SF

NOTE: 1% FS OF THE TAPE RECORDER OUTPUT CORRESPONDS TO A 10 MV PEAK DISCRETE FREQUENCY SINE WAVE USED TO CALIBRATE THE SPECTRUM ANALYZER.

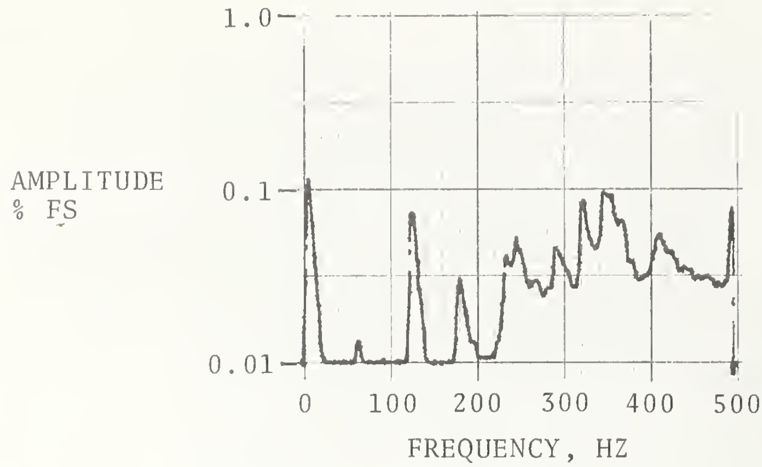
- RUN 300/2
- CLOCKWISE
- SAMPLE SERVICE
- 500 Hz RANGE

FIGURE D-9. TEMPERATURE NOISE SIGNAL EQT-3 FREQUENCY SPECTRA

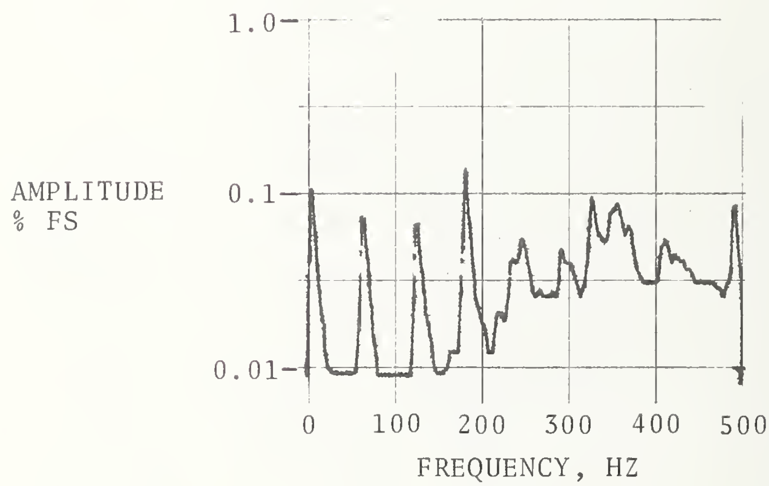


- RUN 300/2
- SAMPLE SERVICE
- CLOCKWISE
- SIGNAL BANDWIDTH - 40 Hz

FIGRE D-10. TEMPERATURE REDUNDANT SIGNAL CHART RECORD



TAPE NOISE AT ZERO VOLT CAL



STPS-2 NOISE DURING CONSTANT VEHICLE SPEED

NOTE: 1.0% FS OF THE TAPE RECORDER OUTPUT CORRESPONDS TO A 10 MV PEAK DISCRETE FREQUENCY SINE WAVE USED TO CALIBRATE THE SPECTRUM ANALYZER.

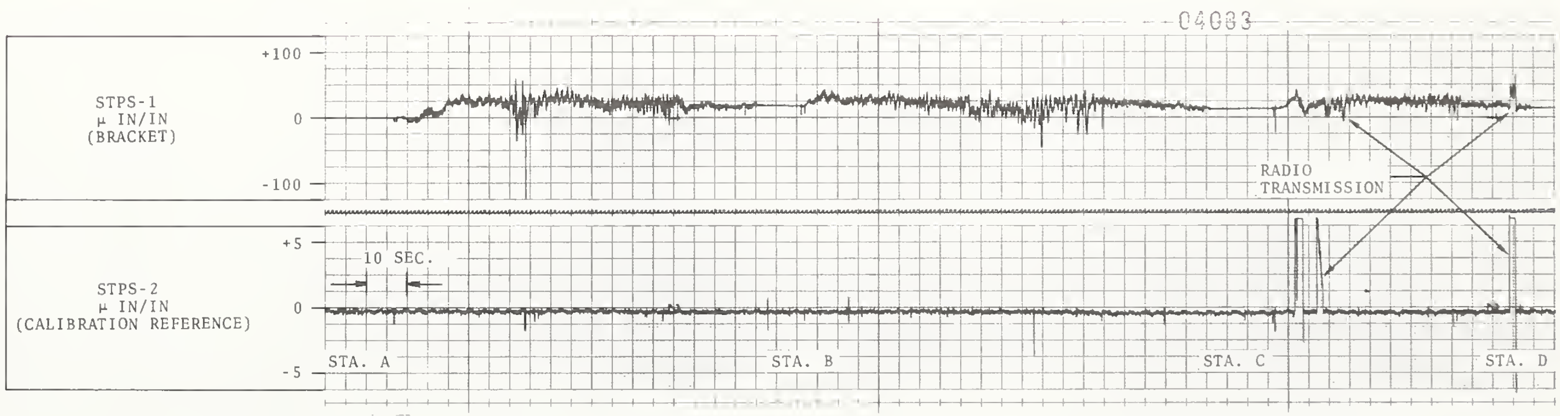
- RUN 300/2
- CLOCKWISE
- SAMPLE SERVICE
- 500 Hz RANGE

FIGURE D-11. STRAIN NOISE SIGNAL STPS-2 FREQUENCY SPECTRA

noise and system noise. The STPS-2 noise has increased amplitude at 60 and 180 Hz but all components are more than 60 dB below the system full scale level.

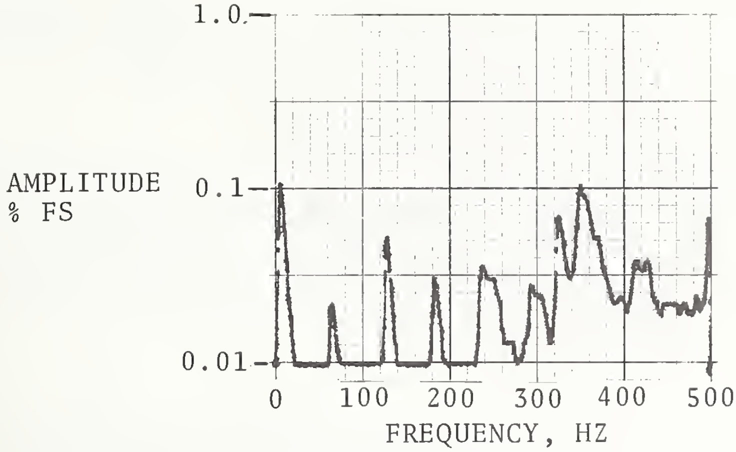
Bracket Strain Data

Figure D-12 is a chart recording of strain data at the beginning of run 300/2. Both STPS-1 and STPS-2 are shown. The amplitude of the bracket strain signal (40 Hz response) was ± 50 μ in/in. Figure D-13 displays frequency spectra of the strain signal and tape noise. The 35 Hz peak may correspond to a structural resonance.

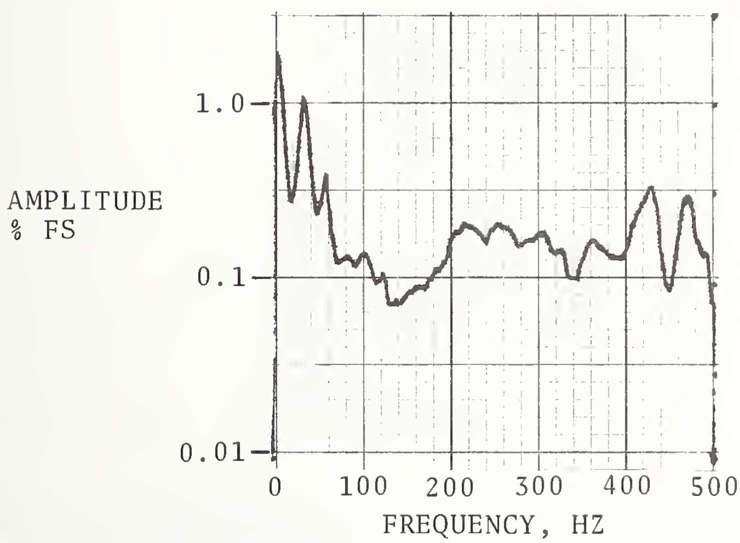


- RUN 300/2
- SAMPLE SERVICE
- CLOCKWISE
- SIGNAL BANDWIDTH - 40 Hz

FIGURE D-12. BRACKET STRAIN SIGNAL CHART RECORD



TAPE NOISE AT ZERO VOLT CAL



STPS-1 SIGNAL DURING CONSTANT VEHICLE SPEED

NOTE: 1.0% FS OF THE TAPE RECORDER OUTPUT CORRESPONDS TO A 10 MV PEAK DISCRETE FREQUENCY SINE WAVE USED TO CALIBRATE THE SPECTRUM ANALYZER.

- RUN 300/2
- CLOCKWISE
- CONSTANT SPEED
- 500 Hz RANGE

FIGURE D-13. BRACKET STRAIN SIGNAL STPS-1 FREQUENCY SPECTRA

TEST SET	TEST TITLE: Displacement Systems Evaluation TEST SET NO.: R42-I-5302-TT

TEST OBJECTIVE: To determine the operational characteristics of the two displacement measurement systems: potentiometer and non-contact.

TEST DESCRIPTION: The test vehicle was operated under simulated GVT procedures including accel/decel and sample service. Parameters determined include:

1. Zero signal drift
2. Noise pickup
3. Shock/vibration effects
4. Redundant data comparison

STATUS: Sufficient data was collected to evaluate the displacement systems. No equipment malfunctions were experienced.

FIGURE D-14. DISPLACEMENT SYSTEM EVALUATION TEST SUMMARY

D2 DISPLACEMENT SYSTEMS EVALUATION

D2.1 TEST SUMMARY

See Figure D-14 preceding.

D2.2 PROCEDURE

Displacemnt measurement systems can be used to determine the dynamic motions of the vehicle suspension system, couplers, drawbars, or any other vehicle component. The measurements are especially useful when tracing the dynamic load paths of a vehicle, or determining the sources of ride roughness acceleration components.

Two types of sensor systems were tested. The most common utilizes a wirewound potentiometer whose wiper is rotated by displacing an extension cable wound on a pulley. The pulley is spring loaded to maintain tension on the cable. A dc voltage is impressed across the pot with the wiper acting as a voltage divider to provide the output signal. The second sensor system is a non-contact type. A probe containing two coils is placed near a conducting surface. Eddy currents are established in the surface and the resulting signal loss upsets the coupling between the coils. The probes can be calibrated to provide an output voltage linearly related to the probe/target separation distance.

To obtain representative data from various vehicle locations, the sensors were mounted as shown in Figure D-15. The sensor nomenclature refers to GVTP standard outputs.

STPD	Structural Test Parameter Displacement

The purpose of each displacement measurement was:

STPD-1, STPD-2	Redundant Displacement Pot Data From Swing Link
STPD-3	Noise Pick-up
STPD-4, STPD-5	Carbody Vibration Effects
STPD-6, STPD-7	Displacement Pot Vs. Non-Contact Sensor
STPD-8	Truck Vibration Effects

The installations of STPD-1 and STPD-2 are shown in Figure D-16. The carbody mounted sensor, STPD-4, is shown in Figure D-17. Figure D-18 displays the pot versus non-contact sensor locations. STPD-8 is shown in Figure D-19.

The ACT I synthetic transit route with station stops was used for this test. This route is described in paragraph C1.2.

D2.3 INSTRUMENTATION

A block diagram of the displacement measurement systems test is given in Figure D-20.

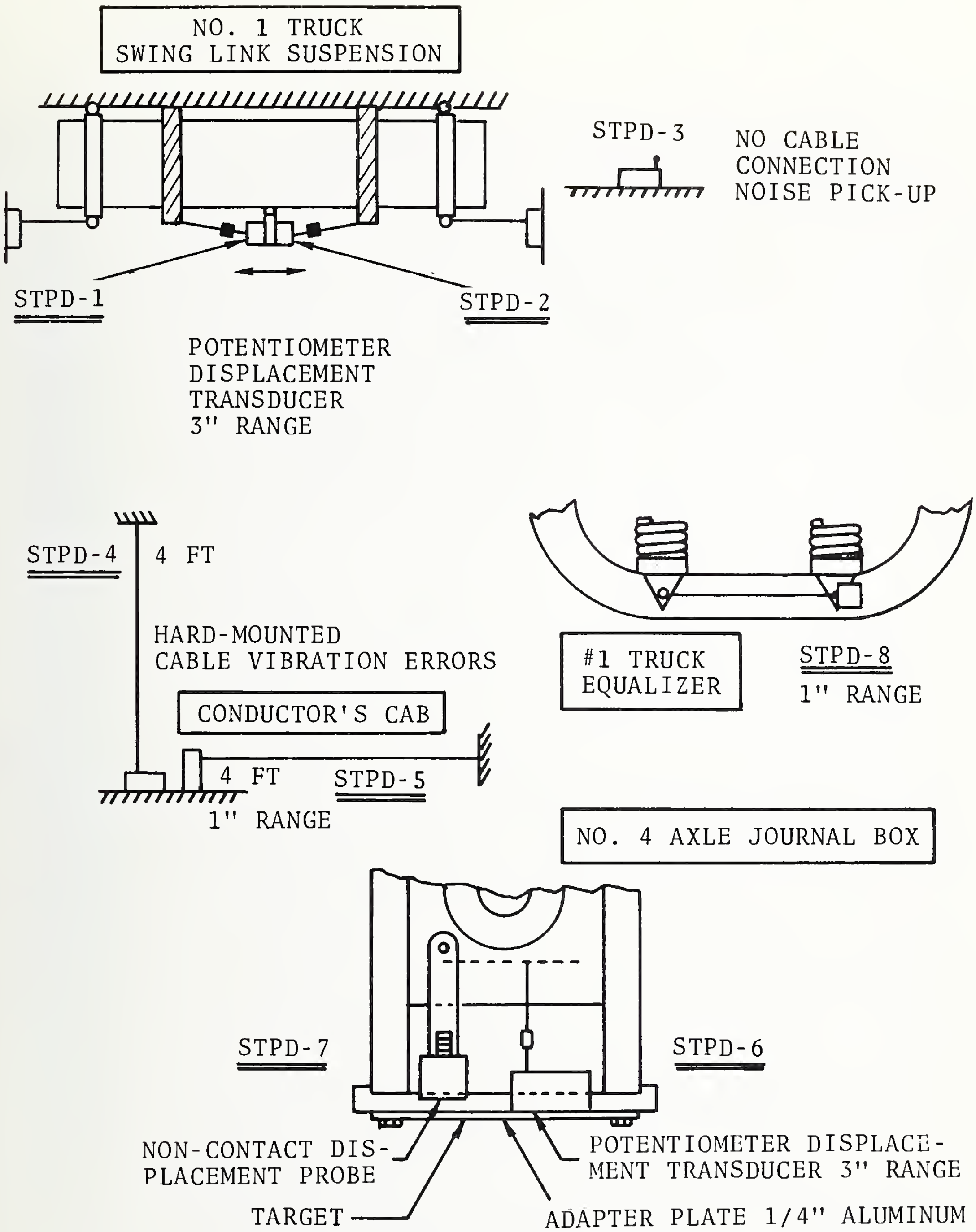


FIGURE D-15. SCHEMATIC OF DISPLACEMENT SENSOR TEST INSTALLATION

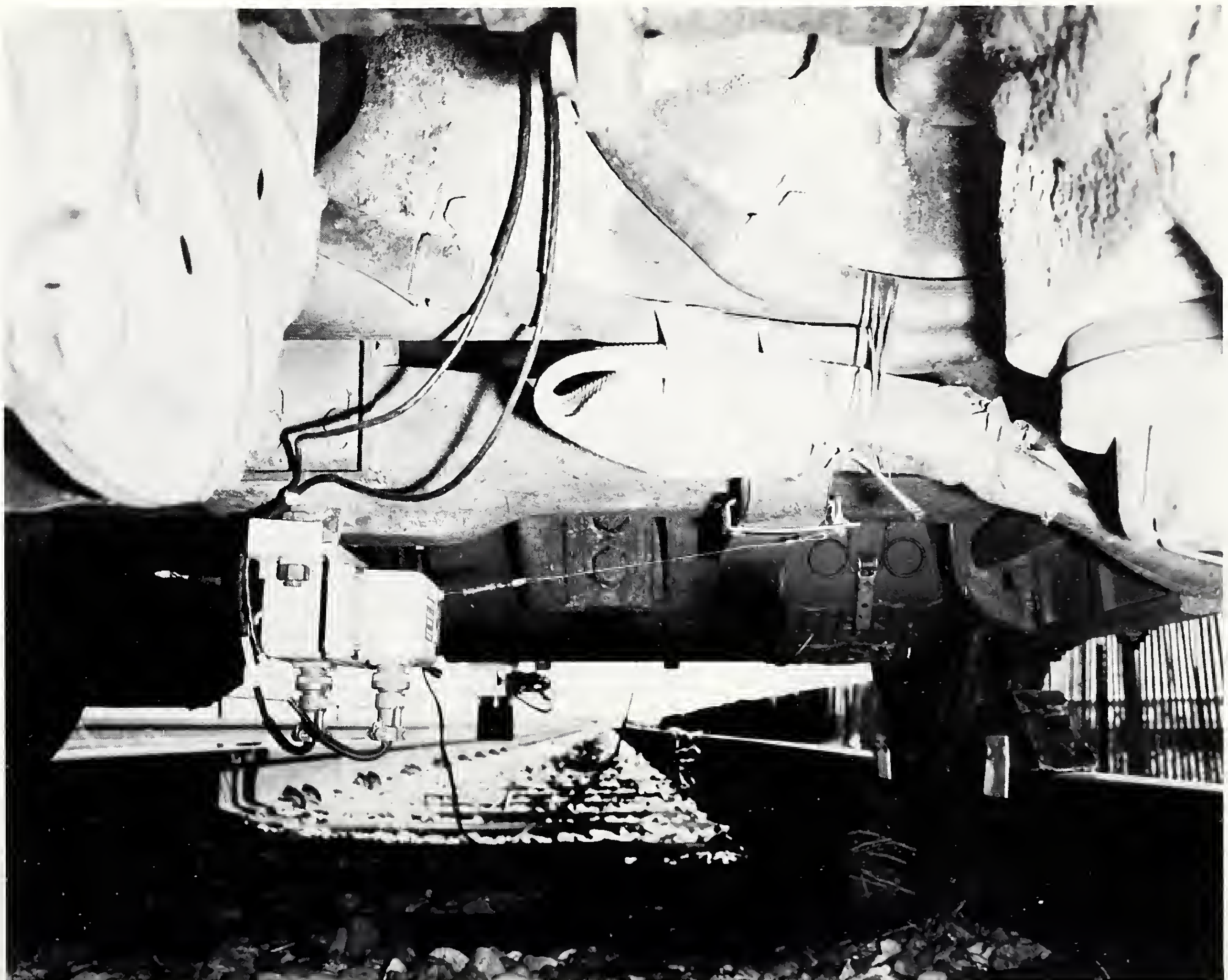


FIGURE D-16. SWING LINK POTENTIOMETER DISPLACEMENT SENSOR INSTALLATION, NO. 1 TRUCK

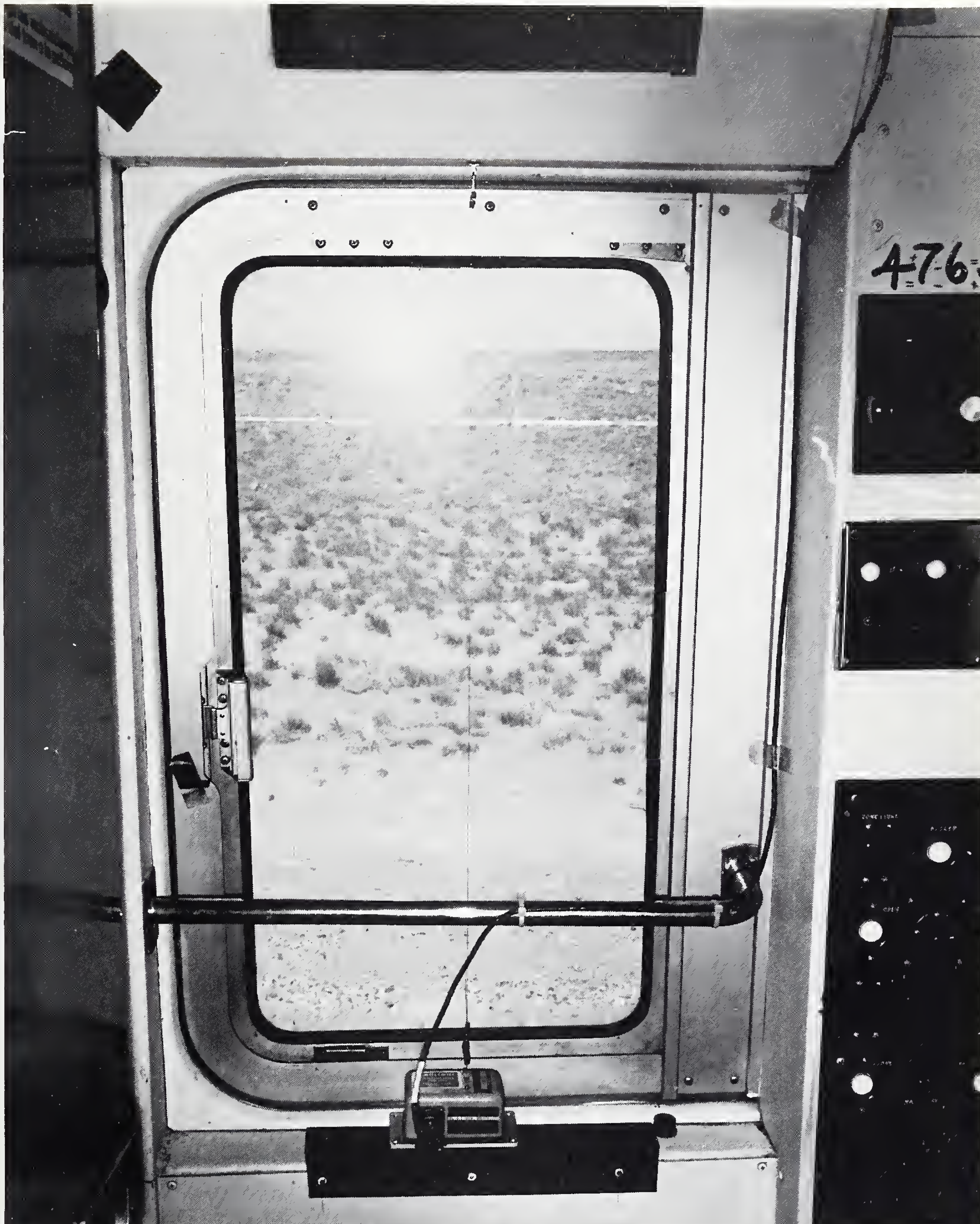


FIGURE D-17. VERTICAL ZERO-SIGNAL POTENTIOMETER DISPLACEMENT SENSOR INSTALLATION, CONDUCTOR'S CAB

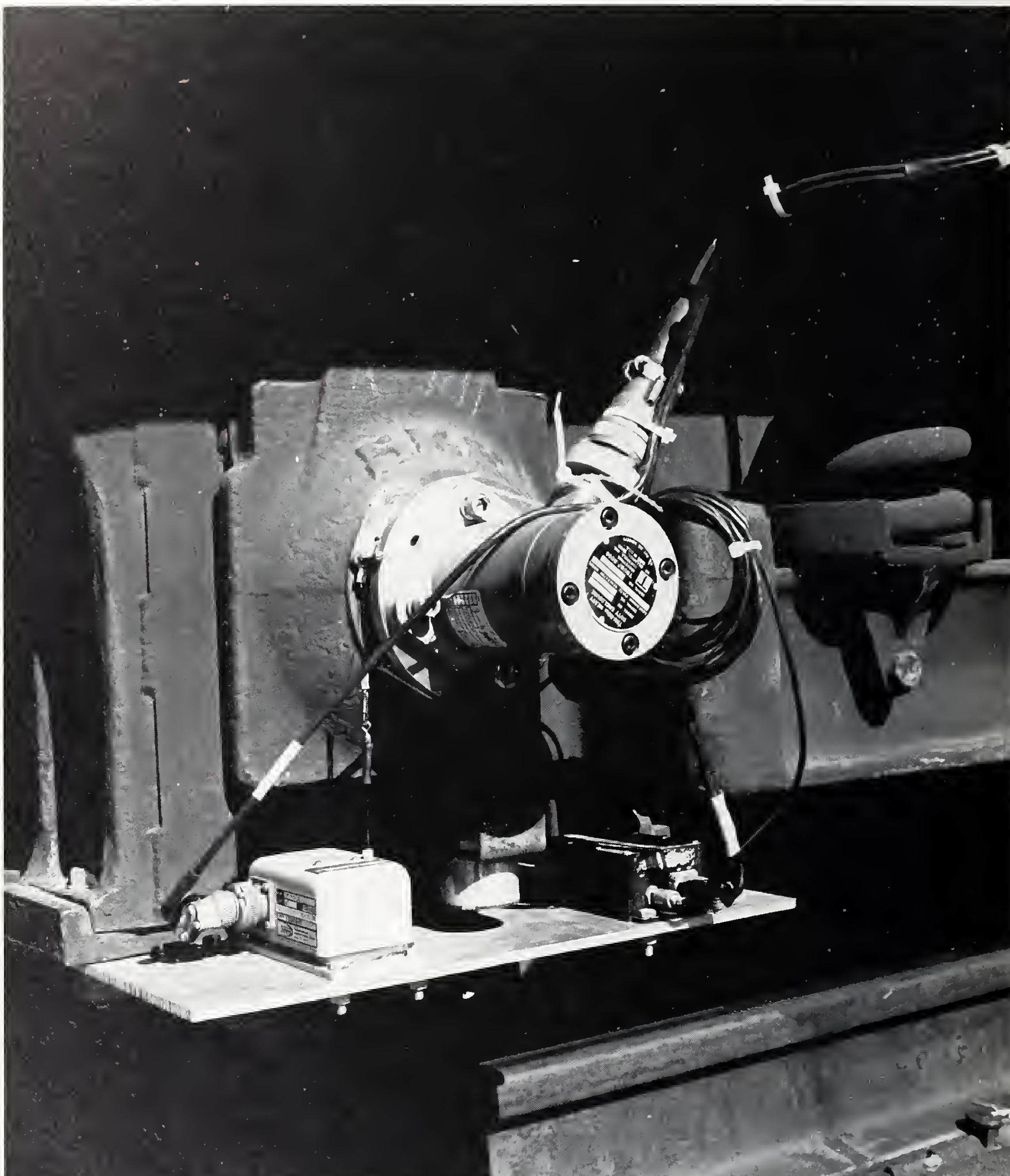


FIGURE D-18. JOURNAL BOX/TRUCK FRAME DISPLACEMENT SENSOR INSTALLATION, POTENTIOMETER AND NON-CONTACT TYPES

FIGURE D-19. LONGITUDINAL ZERO-SIGNAL POTENTIOMETER DISPLACEMENT SENSOR INSTALLATION, EQUALIZER BEAM, NO. 1 TRUCK

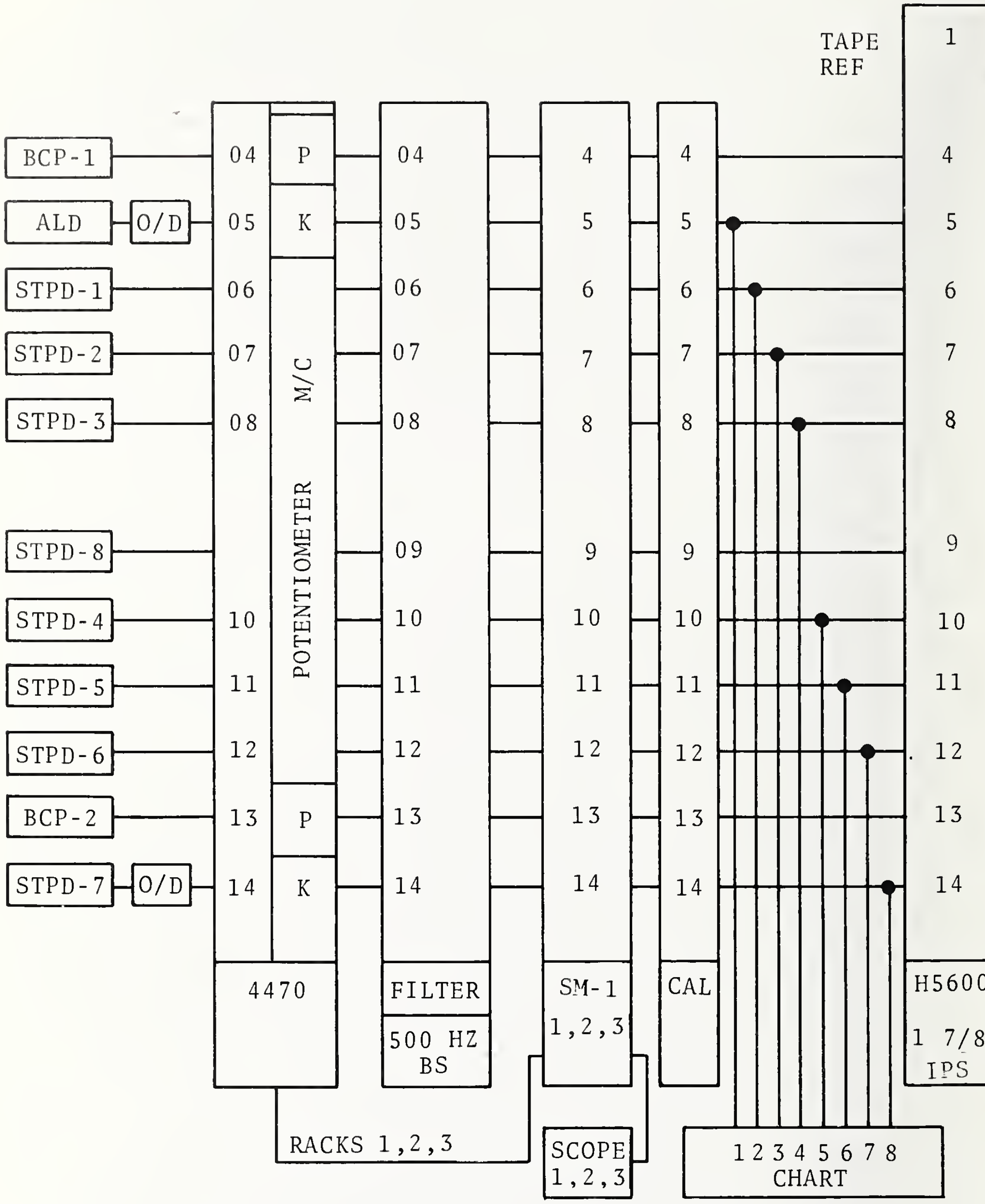


FIGURE D-20. DISPLACEMENT TEST EQUIPMENT, BLOCK DIAGRAM

Type	Mfgr.	Model No.	Qty
Sensors			
Brake Pressure	BLH	Type DHF	2
ALD	Kaman	KD1106-10C	1
Non-Contact Displacement	Kaman	KD1105-10SPL	1
Potentiometer Displacement	Celesco	PT-101	7
Preconditioners			
Oscillator/Demodulator (ALD)	Kaman	KD2300-12CU	1
Oscillator/Demodulator (STPD)	Kaman	KD2300-10SPL	1
Mode Card			
Pressure	Endevco	4476.2AM3 w/TSC Mod P	2
ALD/DISP	Endevco	4475.1 w/TSC Mod K	2
Pot Displacement	Endevco	4471.3	7

All other items in the block diagram are discussed in Appendix A.

D2.4 PROCEDURES

I PRELIMINARY

A. Install test equipment as shown in Figures D-15 and D-20.

B. Verify signal routing by simulation.

C. Complete log documentation sheets.

II TEST

A. Proceed to test loop.

B. Verify system operation.

C. Calibrate tape unit:
1 minute @ 0.0 volts,
1 minute @ 5.0 volts.

D. Power rail.

E. Observe zero signal levels on scope.

F. Operate vehicle on command of Chief Test Engineer.

G. Debug and log-document all problems on each channel.

H. Operate vehicle in a sample service mode described below:

1. Use synthetic transit route CW beginning at Station A.

2. Calibrate recorder at station stops A, E, J, O.

3. Zero signal conditioners prior to run.

4. Record pertinent information on voice track and chart record.

D2.5 PRELIMINARY DATA ANALYSIS

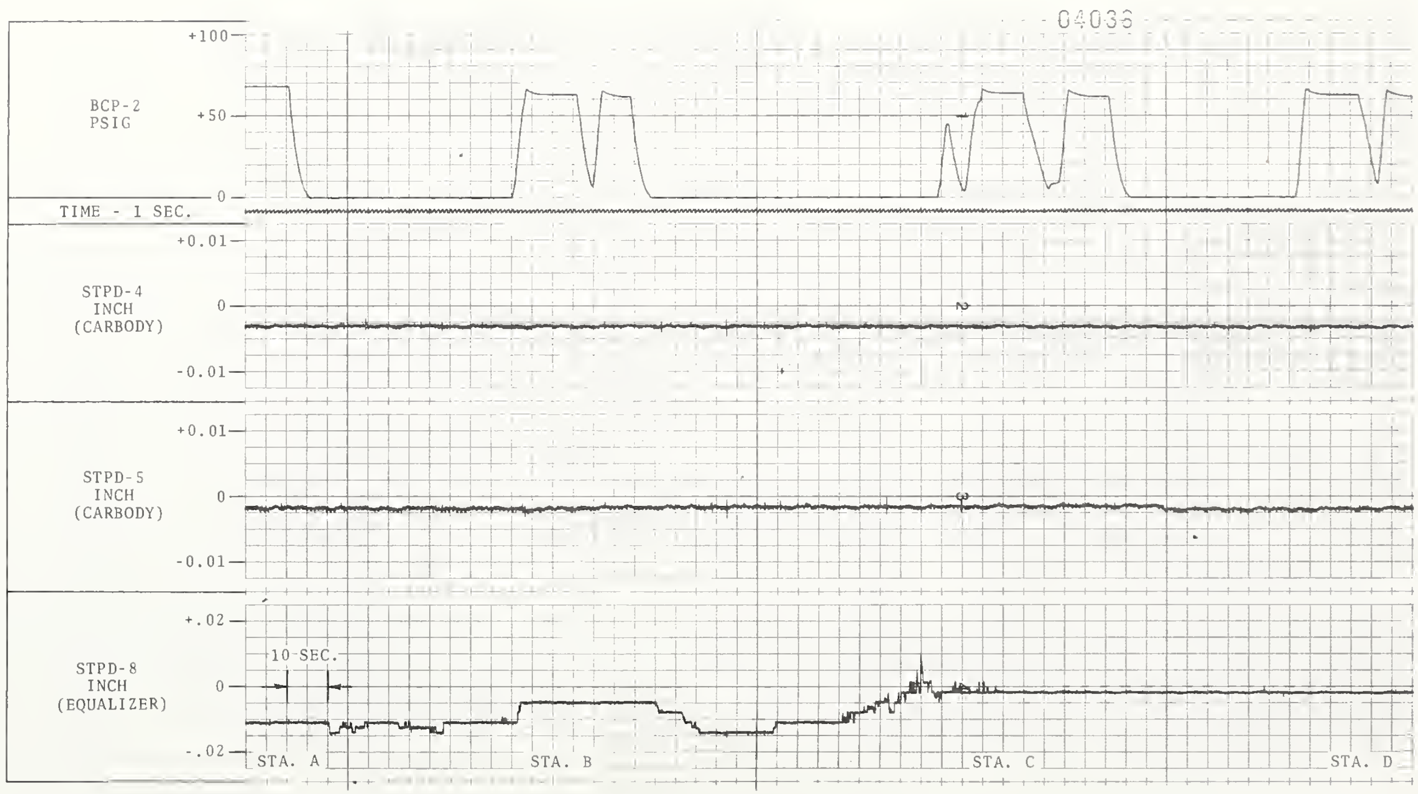
The data selected for detailed analysis was collected on run 300/4. This run was a clockwise, sample service run using the synthetic transit route. The run lasted 24 minutes. All data was recorded at 1 7/8 ips with a maximum filter bandwidth of 500 Hz.

D2.5.1 Potentiometer Displacement System

Zero Signal Drift

Three one-inch range sensors were installed with their extension cables hard-mounted to the vehicle. STPD-4 and STPD-5 were mounted in the conductors cab. Output drift of these two sensors was less than 0.1 percent FS.

STPD-8 was mounted on the truck equalizer beam. DC signal shifts of +1.0 and -3.5 percent FS were evident on this channel. The occurrence of these errors roughly correlates to the vehicle braking effort. See Figure D-19, which shows that the sensor was mounted on the equalizer spring pad. Small rotational motions of this pad could have induced the displacements noted above (+.005, -.017 inch). Figure D-21 displays a chart recording of the three data channels. The brake cylinder pressure trace is included for reference.



• RUN 300/4
• SAMPLE SERVICE
• CLOCKWISE
• SIGNAL BANDWIDTH - 40 Hz

FIGURE D-21. POTENTIOMETER DISPLACEMENT SENSOR ZERO-SIGNAL CHART RECORD

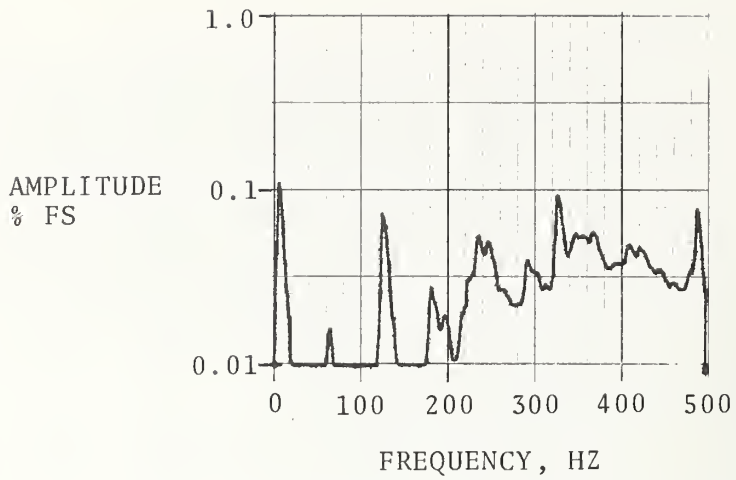
Noise Pick-up

Frequency spectra were generated for STPD-4 and STPD-5 during vehicle movement. The spectra were compared to the tape recorded calibrate signal spectra with no significant differences observed. Plots of the tape noise and STPD-4 spectra are shown in Figure D-22.

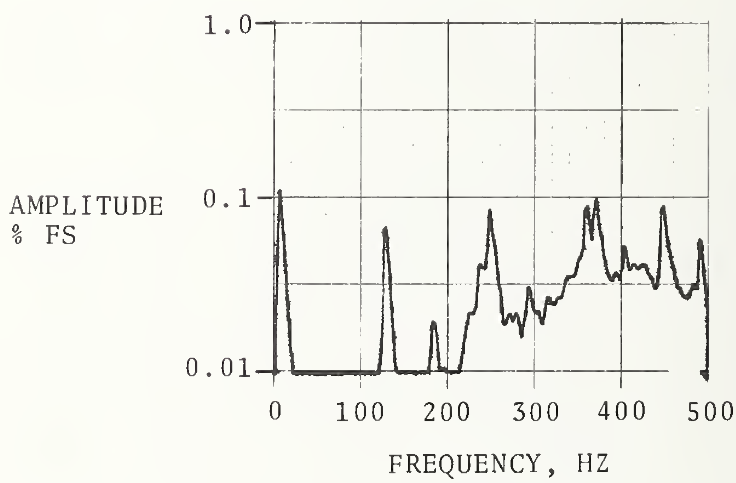
Redundant Data Comparison

The swing link sensors, STPD-1 and STPD-2, were installed such that lateral motion of the bolster would induce signals in both sensors of equal magnitude but opposite polarity. A summation of the signals would ideally produce a zero output. Figure D-23 is a chart recording of the two sensor outputs and their summation signal. Figure D-24 is a time and amplitude expanded chart of a portion of the same data between stations B and C.

At each station stop, the swing link assumed a static displacement dependent upon the road bed cross level. Observation of the chart record of the whole run indicates the static summation error is less than 1 percent FS (0.015 inch). The dynamic data displayed in Figures D-23 and D-24 indicate summation errors of -1.0 percent and +3.0 percent FS. A close comparison of STPD-1 and the summation signal of Figure D-24 reveals that the error is greatest when the STPD-1 trace is going negative. This occurs when the displacement pot cable is being retracted. The STPD-1 sensor may have an increased friction in the retraction mechanism that caused a slight time delay between signals during rapid cable retractions.



TAPE NOISE AT ZERO VOLT CAL

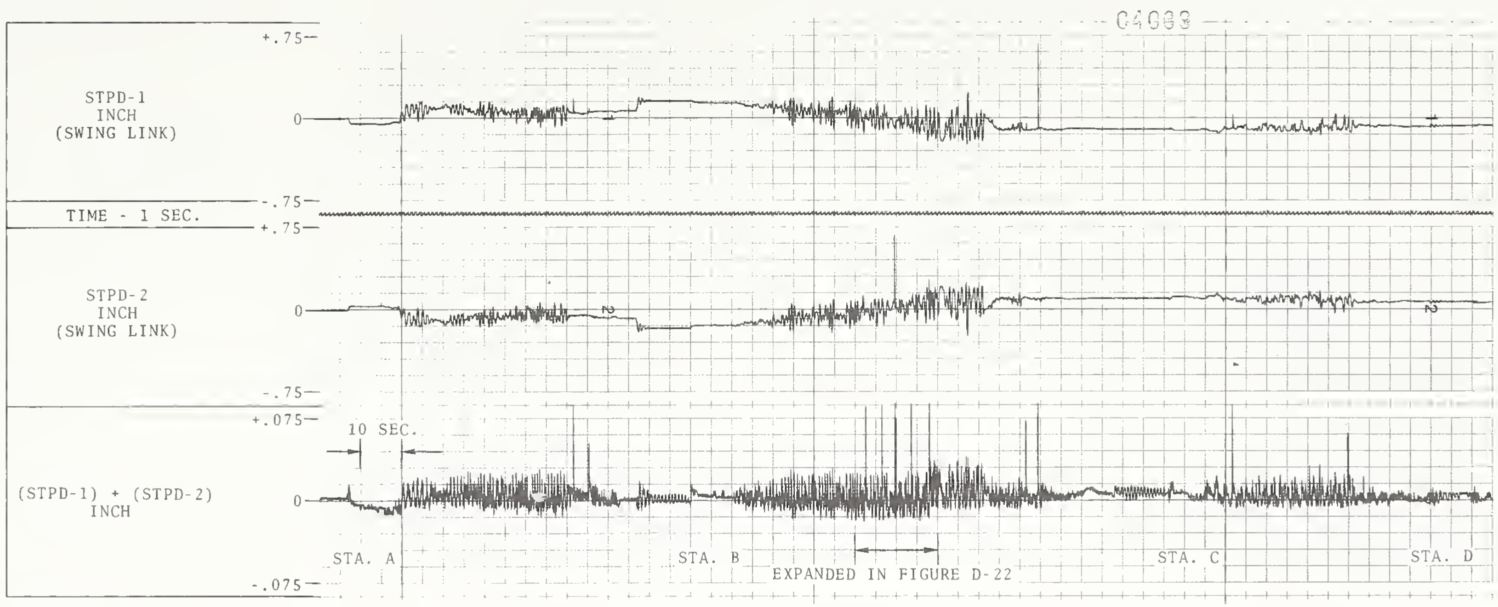


STPD-4
SIGNAL NOISE AT CONSTANT VEHICLE SPEED

NOTE: 1.0% FS OF THE TAPE RECORDER OUTPUT CORRESPONDS TO A 10 MV PEAK DISCRETE FREQUENCY SINE WAVE USED TO CALIBRATE THE SPECTRUM ANALYZER.

- RUN 300/4
- CLOCKWISE
- CONSTANT SPEED
- 500 Hz RANGE

FIGURE D-22. POTENTIOMETER DISPLACEMENT NOISE SIGNAL STPD-4 FREQUENCY SPECTRA



- RUN 300/4
- SAMPLE SERVICE
- CLOCKWISE
- SIGNAL BANDWIDTH - 40 Hz

FIGURE D-23. POTENTIOMETER DISPLACEMENT REDUNDANT SIGNAL CHART RECORD

- RUN 300/4
- SAMPLE SERVICE
- CLOCKWISE
- SIGNAL BANDWIDTH - 40 Hz

CABLE EXTENSION ERROR SIGNALS (CIRCLED) CAUSED BY IMPACTS WITH TRACK DEBRIS.

FIGURE D-24. POTENTIOMETER DISPLACEMENT REDUNDANT SIGNAL CHART RECORD, EXPANDED AMPLITUDE AND TIME SCALES

Five signal transients are also evident in Figure D-24 (circles). These errors are attributed to flying ballast or more likely to tumbleweed between the rails impacting the extension cables. Figure D-16 shows the vulnerability of both swinglink displacement sensors. No other pot sensor exhibited these transients, which were always positive polarity indicating a cable extension.

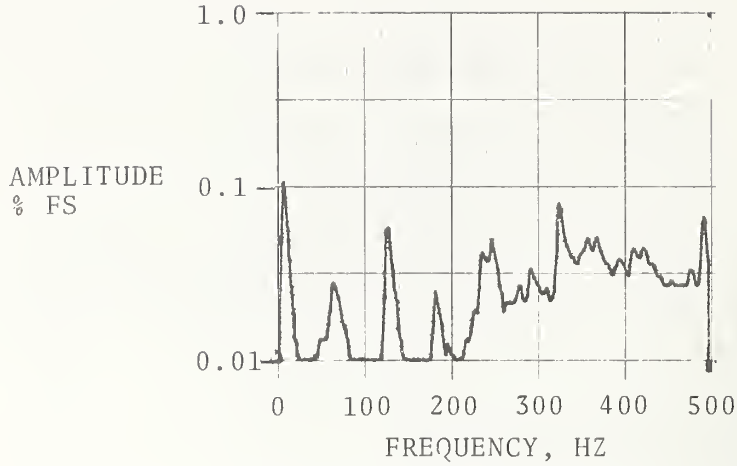
D2.5.2 Non-Contact Displacement

Noise Pick-up

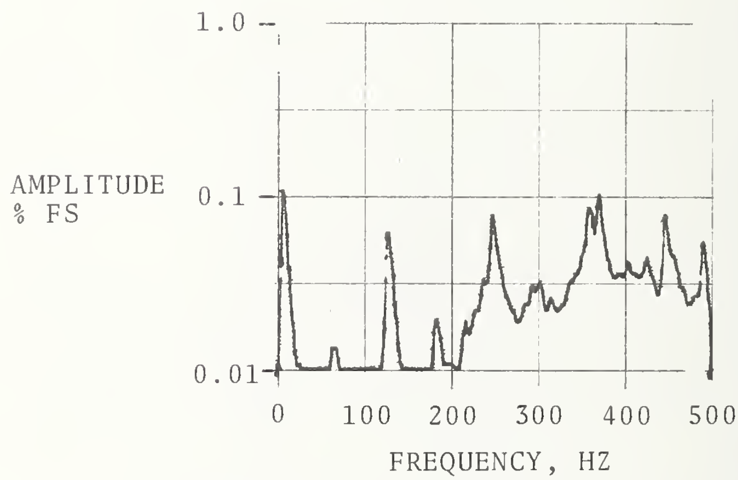
Frequently spectra for STPD-7 and the tape noise are shown in Figure D-5. The vehicle was stationary during this analysis to eliminate signals from actual displacements. No significant differences in the noise spectra are evident.

Redundant Data Comparison

STPD-6 was a displacement pot and STPD-7 was a non-contact displacement probe. Both sensors were installed to simultaneously measure the journal box/truck frame relative displacement as shown in Figure D-18. A chart recording of both signals and their differential summation is given in Figure D-26. Errors exceeding +4% FS are evident when large displacements occurred. These errors are the result of an insufficient pre-test calibration of the non-contact probe. Four adjustment screws are available on the non-contact probe preconditioner. These adjustments trim the oscillator/demodulator circuit to provide a linear output for a given target material and geometry. Testing time constraints prior to this test did not allow a detailed, accurate calibration.



TAPE NOISE AT ZERO VOLT CAL

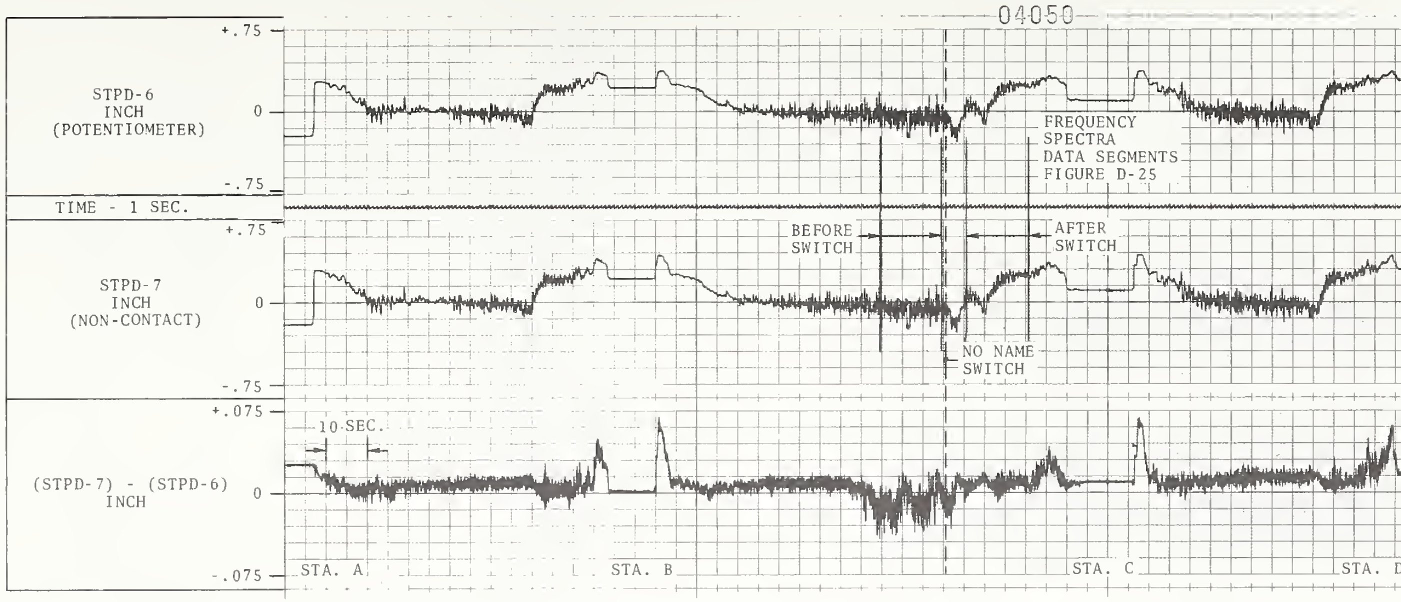


SIGNAL NOISE WITH VEHICLE STATIONARY

NOTE: 1.0% FS OF THE TAPE RECORDER OUTPUT CORRESPONDS TO A 10 MV PEAK DISCRETE FREQUENCY SINE WAVE USED TO CALIBRATE THE SPECTRUM ANALYZER.

- RUN 300/4
- 500 Hz RANGE
- VEHICLE STATIONARY

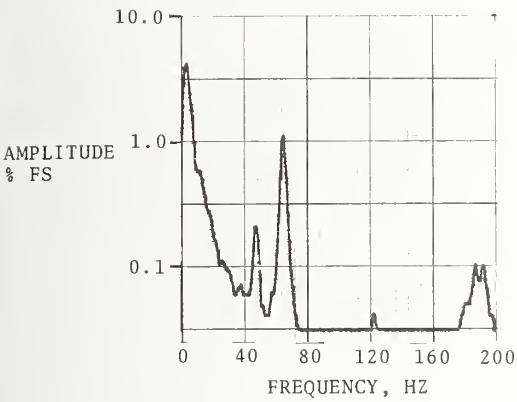
FIGURE D-25. NON-CONTACT DISPLACEMENT NOISE SIGNAL STPD-7 FREQUENCY SPECTRA



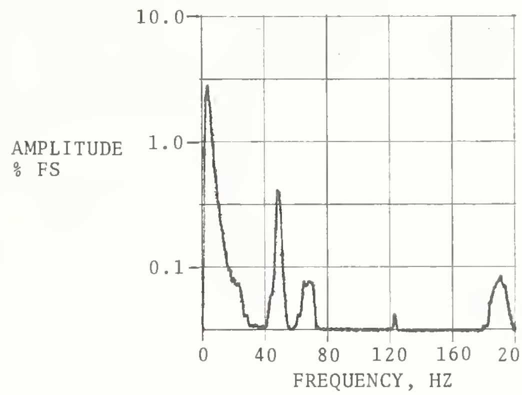
• RUN 300/4 • CLOCKWISE
• SAMPLE SERVICE • SIGNAL BANDWIDTH - 40 Hz

FIGURE D-26. POTENTIOMETER VERSUS NON-CONTACT DISPLACEMENT SIGNAL CHART RECORD

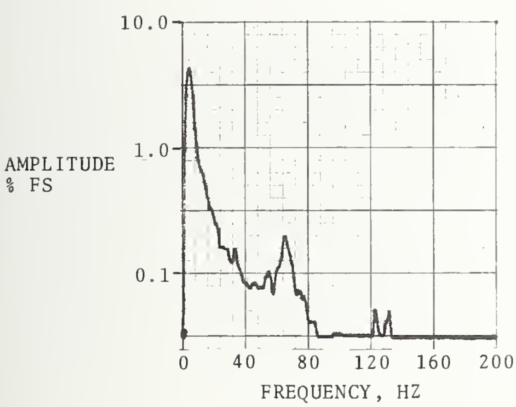
The dynamic response of the displacement pot is a function of the maximum cable retraction acceleration. Assuming a value of 5 g's, the amplitude of a sinusoidal displacement at a frequency of 65 Hz is .012 inch. Therefore, a displacement pot with a 5 g cable retraction acceleration can accurately follow this motion. Four frequency spectra are shown in Figure D-27. These spectra display the non-contact versus pot signal for two different portions of run 300/4. On the left spectra, the 65 Hz signal on the non-contact plot corresponds to a peak displacement of 0.015 inch. The corresponding pot data indicates a 0.003 peak displacement suggesting that the pot did not follow the displacement accurately. On the right spectra, the 65 Hz signal from a different section of the run is 0.001 inch. Both sensors exhibited approximately the same amplitude at this frequency indicating the ability of the pot to follow this lower amplitude motion. The 48 Hz signal which only appears on the non-contact data may be a mechanical resonance in the probe mounting fixture.



STPD-7
NON-CONTACT DISPLACEMENT

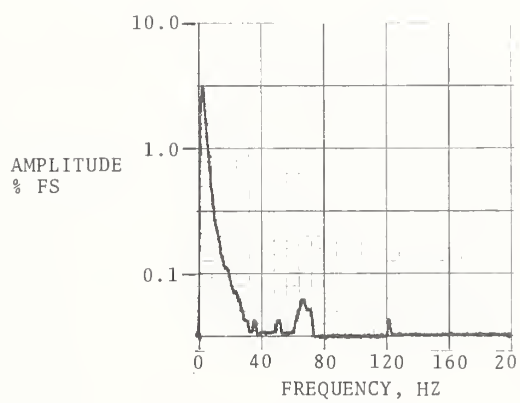


STPD-7
NON-CONTACT DISPLACEMENT



STPD-6
POTENTIOMETER DISPLACEMENT

16 SECOND DATA SEGMENT PRIOR
TO NO-NAME SWITCH ALD



STPD-6
POTENTIOMETER DISPLACEMENT

16 SECOND DATA SEGMENT AFTER
NO-NAME SWITCH ALD

- RUN 300/4
- CLOCKWISE
- CONSTANT SPEED
- 200 Hz RANGE

FIGURE D-27. POTENTIOMETER VERSUS NON-CONTACT DISPLACEMENT SIGNAL FREQUENCY SPECTRA (BEFORE AND AFTER THE NO-NAME SWITCH ALD SIGNAL)

APPENDIX E

ACCELERATION/VIBRATION SYSTEMS EVALUATION

The following test set is discussed in this appendix:

Test Category	Test Set No.	Test Title	Page
Acceleration/ Vibration	R42-I-1110-TT	Acceleration/Vibration	E-3

TEST SET	TEST TITLE: Acceleration/Vibration Evaluation TEST SET NO.: R42-I-1110-TT

TEST OBJECTIVE:

To determine the operational characteristics of the servo and piezo accelerometer systems.

TEST DESCRIPTION: The vehicle was operated under simulated GVT procedures including constant speed, accel/decel and sample service. Equipment set-up yielded data concerning:

1. Zero Signal Drift
2. Noise Pick-up
3. Data Comparison

STATUS: Sufficient data was collected to evaluate the two systems. It is recommended that all sensors be calibrated on a shaker from 5 to 2000 Hz to determine dynamic characteristics.

Figure E-1. Acceleration/Vibration Evaluation Test Summary

E1. ACCELERATION/VIBRATION EVALUATION

E1.1 TEST SUMMARY

See Figure E-1 preceding.

E1.2 PROCEDURE

The use of accelerometers for dynamic measurements is widely accepted. On rail vehicle tests, the accelerometers provide information to determine ride roughness, carbody bending modes, truck responses, and track roughness. Selective use of accelerometers can also isolate vibration sources and mechanical equipment malfunctions.

The servo accelerometers contain a flexural element that deflects when the device is accelerated. A magnetic torque is applied to the element to maintain a neutral position. The current creating the opposing torque is a direct analog of the impressed acceleration. This current flows through a precision resistor and the resulting voltage is conditioned and recorded.

The piezo accelerometers contain a crystal that generates a charge proportional to the acceleration of the case. The charge is converted to a voltage in a preconditioner module and amplified as required.

The servo accelerometers were mounted on the car floor and GVT equipment rack as shown in Figure E-2. Purpose of this installation was to determine the vibration transfer function as described in Appendix F. A "dummy" servo accelerometer was fabricated to simulate a zero acceleration signal. A schematic of this unit is shown in Figure E-3.

A photograph of the accelerometer location is shown in Figure E-4 (circle) with a laboratory photo of servo units in two types of mounting fixtures shown in Figure E-5.

The piezo accelerometers were mounted on the Track Geometry Measurement System (TGMS) bracket as shown in Figures E-6 and E-7. A "dummy" piezo accelerometer was also fabricated using an open circuit accelerometer connector. A laboratory photo of an accelerometer and charge-to voltage converter is shown in Figure E-8.

The sensor nomenclature refers to the GVTP standard outputs.

ACX	Carbody Acceleration, Longitudinal
ACY	Carbody Acceleration, Lateral
ACZ	Carbody Acceleration, Vertical
AJX	Journal Acceleration, Longitudinal
AJY	Journal Acceleration, Lateral
AJZ	Journal Acceleration, Vertical

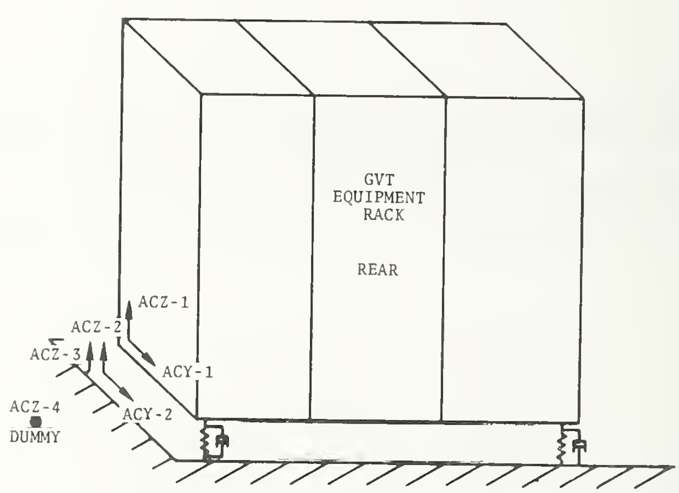
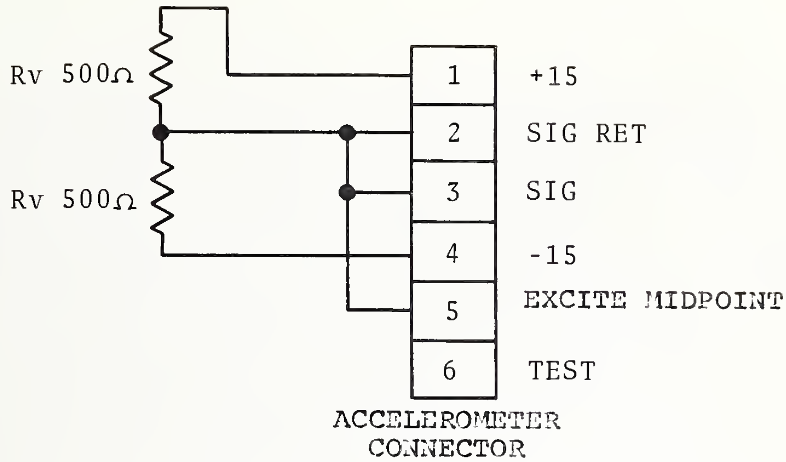


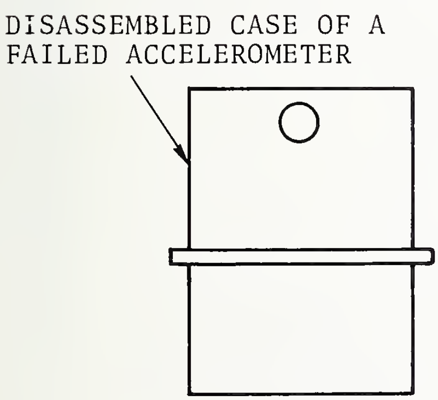
FIGURE E-2. SCHEMATIC OF SERVO ACCELEROMETER TEST INSTALLATION, R42 CAR FLOOR AND EQUIPMENT RACK

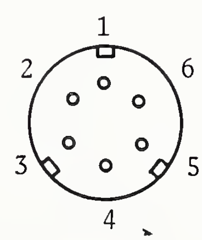


ELECTRICAL SCHEMATIC

30 VDC @ 30 MA

2 Rv = 1KΩ





CONNECTOR LAYOUT

FIGURE E-3. SCHEMATIC OF SERVO ACCELEROMETER ZERO-G SIMULATOR

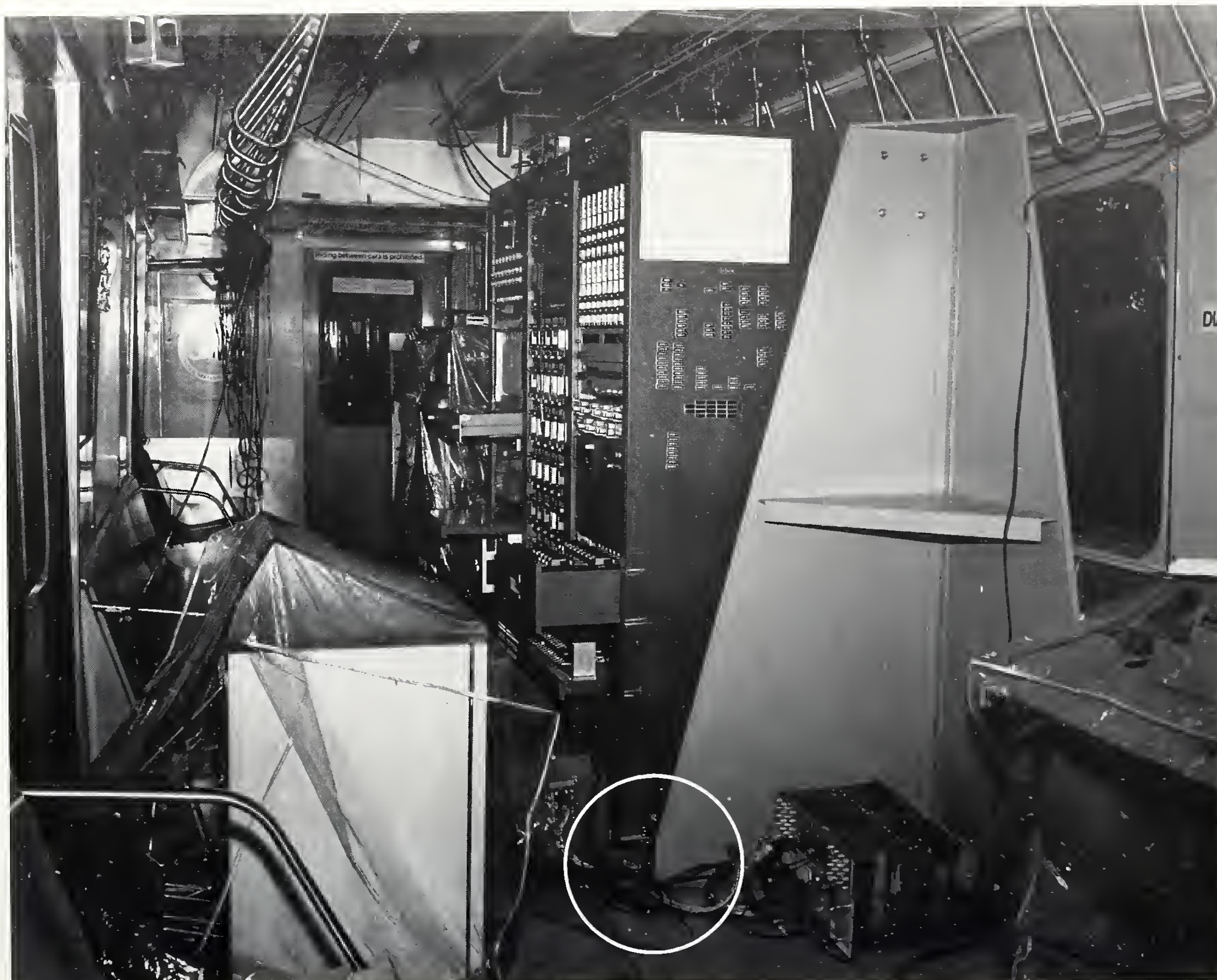


FIGURE E-4. SERVO ACCELEROMETER TEST INSTALLATION, CAR FLOOR AND EQUIPMENT RACK LOCATIONS (CIRCLED)

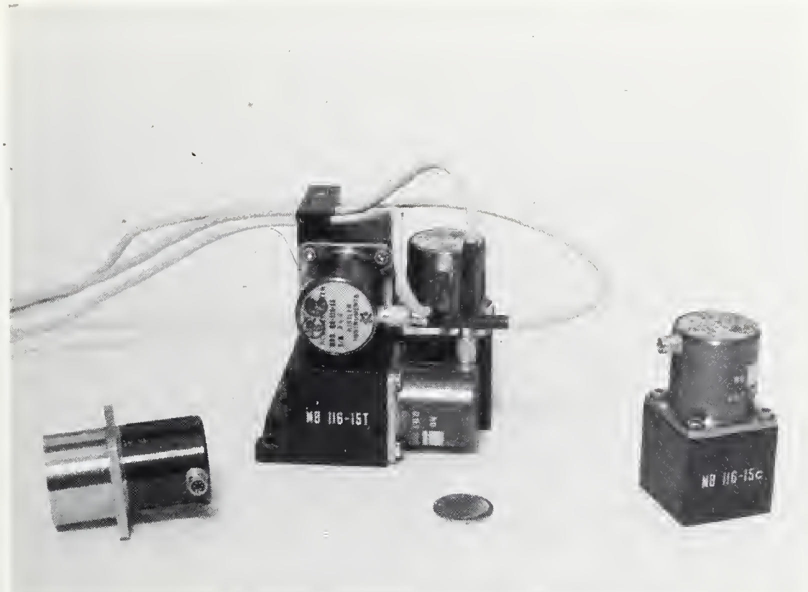


FIGURE E-5. SERVO ACCELEROMETERS AND MOUNTING FIXTURES

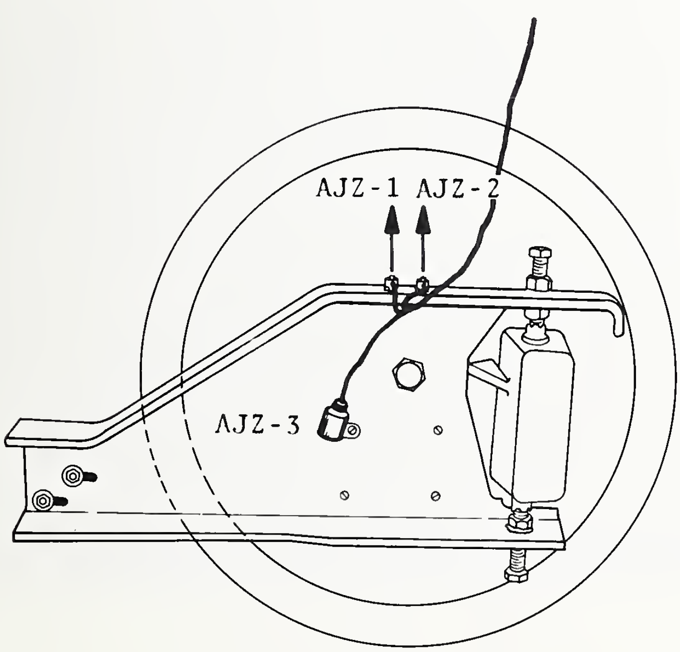


FIGURE E-6. SCHEMATIC OF PIEZO ACCELEROMETER TEST INSTALLATION

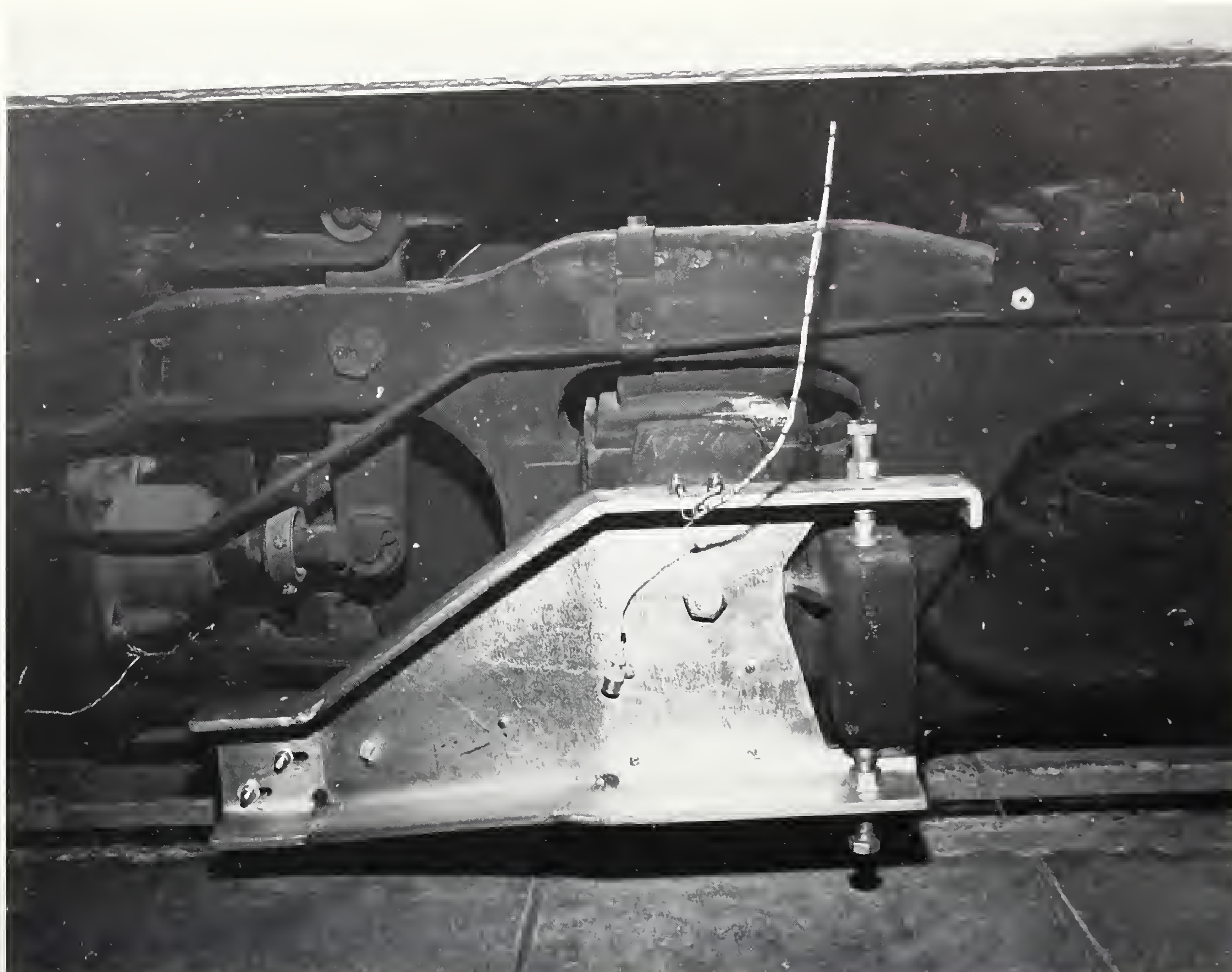


FIGURE E-7. PIEZO ACCELEROMETER TEST INSTALLATION, TRACK GEOMETRY MEASUREMENT SYSTEM BRACKET, NO. 1 TRUCK

FIGURE E-8. PIEZO ACCELEROMETER AND CHARGE-TO-VOLTAGE CONVERTER

The purpose of each acceleration measurement was:

Servo Accelerometers	ACZ-1	Rack vertical acceleration
	ACZ-2	Car floor vertical acceleration
	ACZ-3	Redundant car floor vertical acceleration
	ACZ-4	Simulated zero-G carbody acceleration
	ACY-1	Rack lateral acceleration
	ACY-2	Car floor lateral acceleration
Piezo Accelerometers	AJZ-1	Journal vertical acceleration
	AJZ-2	Redundant journal vertical acceleration
	AJZ-3	Simulated zero-G journal acceleration

The primary test track section was between stations 310 and 330. Constant speed runs were performed from 15 to 55 mph over this section. In addition a full loop at 55 mph was made to determine maximum journal accelerations.

E1.3 INSTRUMENTATION

A block diagram of the accelerometer test is given in Figure E-9.

Sensors

Type	Mfgr.	Model No.	Qty
ALD	Kaman	KD 1106-10C	1
Servo Accelerometer	Endevco/Kistler	QA-116-15	5
Piezo Accelerometer	Columbia	704	2
Preconditioner			
Oscillator/Demodulator	Kaman	KD2300-12CU	1
Charge Converter	Endevco	2652	3
Mode Card			
ALD	Endevco	4475.1 w/TSC Mod K.	1
Servo Accelerometer	Endevco	4479.2	6
Piezo Accelerometer	Endevco	4479.1M2	3

All other items on the block diagram are discussed in Appendix A.

E1.4 PROCEDURES

I PRELIMINARY

A. Install equipment as shown in Figures E-2, E-6 and E-9.

B. Verify system operation by tapping each accelerometer and tracing signal.

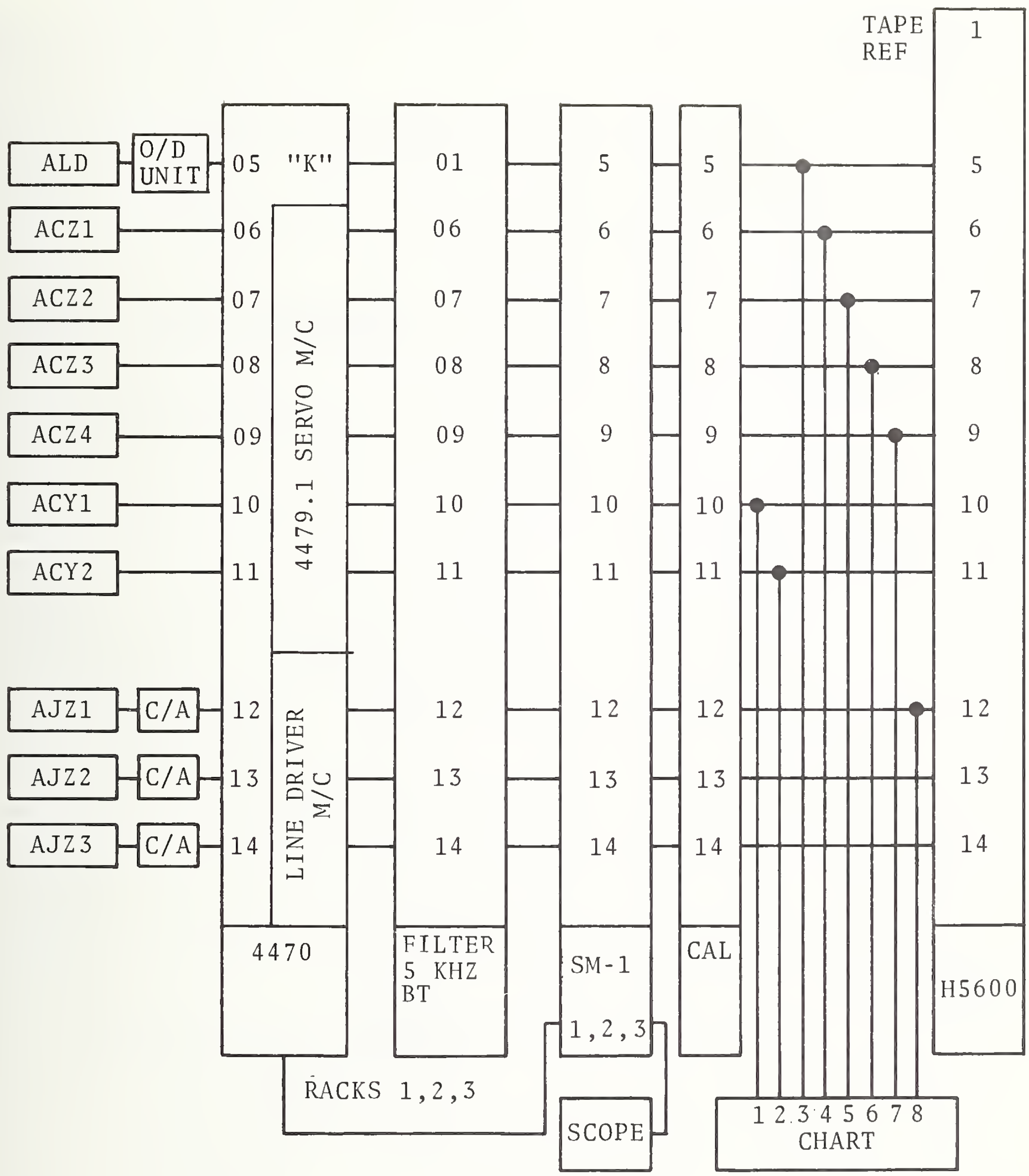


FIGURE E-9. ACCELERATION TEST EQUIPMENT, BLOCK DIAGRAM

C. Complete log entries.

D. Verify noise levels with vehicle static.

II TEST

A. Operate vehicle in a convenient direction on RTTT at 30 mph.

B. Verify operation of system.

C. Observe the output of each channel on scope. Correct any obvious deficiencies.

D. After system debugging, perform the following test runs:

Run Number	Speed mph	Test Stations	Direction
1	50	330-310	CCW
2	20	310-330	CW
3	25	330-310	CCW
4	30	310-330	CW
5	35	330-310	CCW
6	40	310-330	CW
7	45	330-310	CCW
8	50	330-310 (Full Circuit)	CCW

E1.5 PRELIMINARY DATA ANALYSIS

The data selected for detailed analysis was collected on run 400/8. This run was a 55 mph constant speed run, over the entire test track. The tape speed was 15 ips with a resulting data bandwidth of 5KHz. This discussion is divided into servo and piezo accelerometer data.

E1.5.1 Servo Accelerometer

Zero Signal Drift

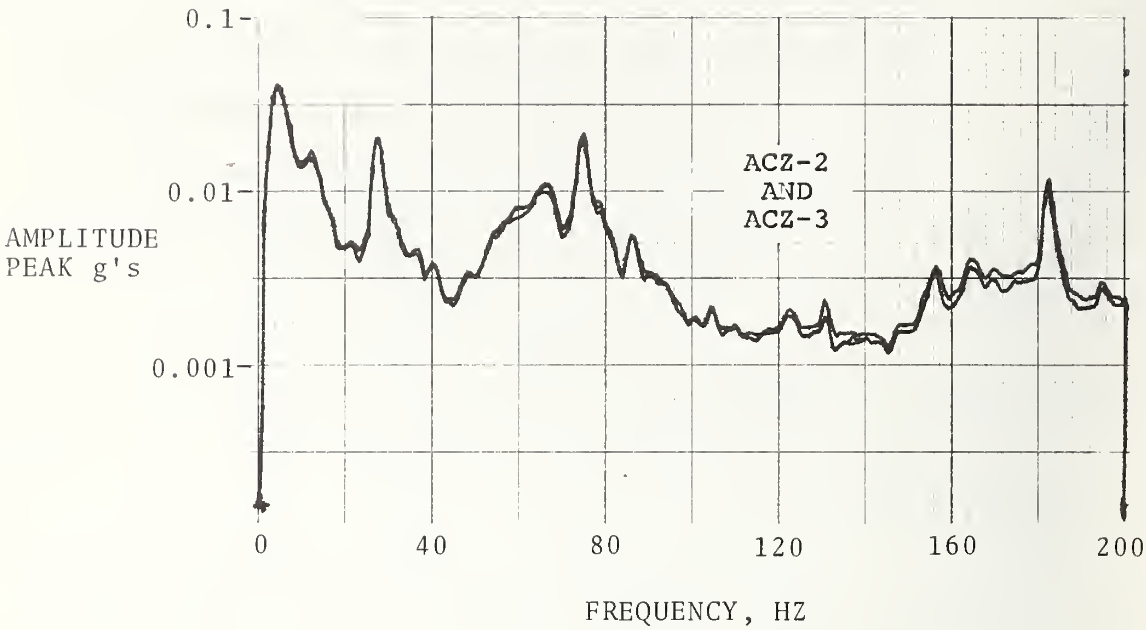
Zero signal tape calibrations were recorded during run 400/2 and following run 400/8. Approximately 60 minutes elapsed between these tape calibrations. Comparison of the simulated zero-g accelerometer signal (ACZ-4) during this time indicated a signal drift of 0.3 percent FS, which is equivalent to 1.5 milli-g.

Noise Pick-up

A 200 Hz frequency spectrum with a full scale calibration of 0.01 g was generated from ACZ-4 on run 400/8. All spectral components were below the 54 dB dynamic range of the analyzer. As a result, all noise components were less than 20 micro-g's peak.

Redundant Data Comparison

The ACZ-2 and ACZ-3 were floor mounted units with their sensitive axes parallel. From laboratory data, both of the test units exhibited a flat frequency response ($\pm$0.5 dB) from DC to 600 Hz. Figure E-10 displays frequency spectra of both signals during run 400/8. Agreement of the plots is within $\pm$1.0 dB.



- RUN 400/8
- 55 MPH
- COUNTERCLOCKWISE
- 200 Hz RANGE

FIGURE E-10. SERVO ACCELEROMETER REDUNDANT SIGNAL FREQUENCY SPECTRA

Figure E-11 is a chart recording of vertical accelerometer data. The floor vertical signal is shown as are the simulated zero-g signal and the shock-mounted rack vertical acceleration signal. An analysis of the rack shock mount characteristics is given in Appendix F.

E1.5.2 Piezo Accelerometer

Zero Signal Drift

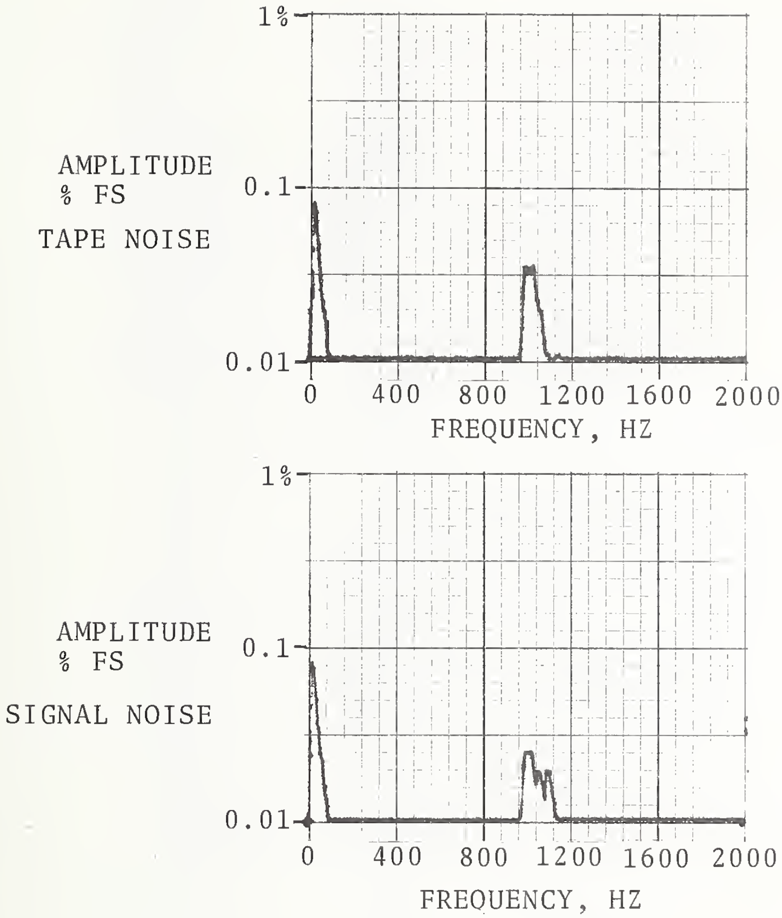
Zero signal tape calibrations were recorded during run 400/2 and following run 400/8. Approximately 60 minutes elapsed between these tape calibrations. Monitoring of the simulated zero-g accelerometer signal (AJZ-3) occurred during this time. Compensation for tape drift yielded an accelerometer drift of 0.1 percent FS. This low signal drift was expected because the piezo accelerometer system has a low frequency cut-off (-3 dB) at 3 Hz.

Noise Pick-up

A 2000 Hz frequency spectrum with a full scale sinusoidal calibration of 1.2 g's peak was generated from AJZ-3 on run 400/8. Figure E-12 displays the zero calibration tape noise and the AJZ-3 noise. No significant difference is noted.

- RUN 400/8
- 55 MPH
- COUNTERCLOCKWISE
- EFFECTIVE SIGNAL BANDWIDTH - 320 Hz

FIGURE E-11. SERVO ACCELEROMETER VERTICAL SIGNAL CHART RECORD



- RUN 400/8
- COUNTERCLOCKWISE
- 55 MPH
- 2000 Hz RANGE

FIGURE E-12. PIEZO ACCELEROMETER NOISE SIGNAL FREQUENCY SPECTRA

Redundant Data Comparison

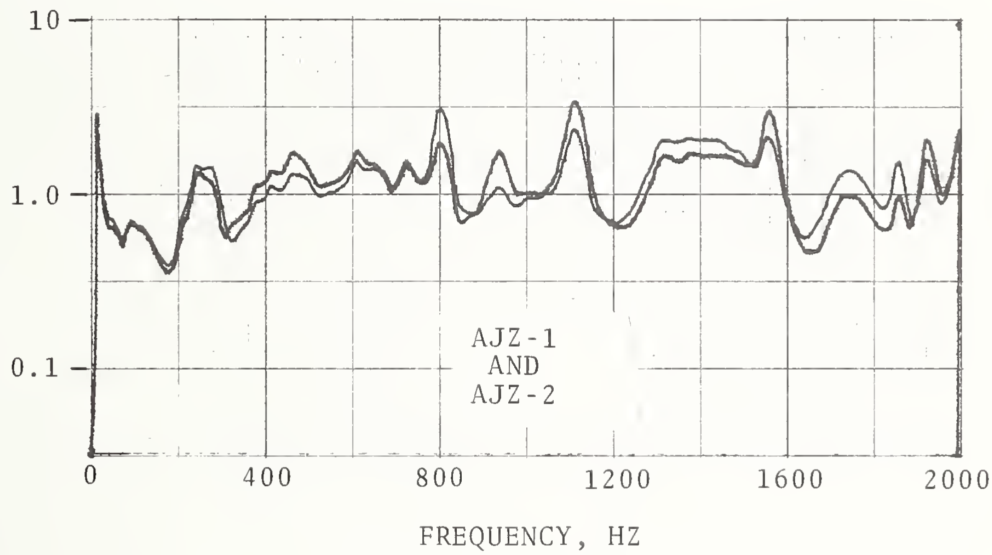
The AJZ-1 and AJZ-2 were both mounted on the track geometry bracket with their sensitive axes parallel. Figure E-13 is a time expanded chart recording of the piezo accelerometer data signals. Full scale settings during the test were 60 g's. Vehicle speed during the run was 55 mph. From the chart, the maximum acceleration was 45 g's and appears to be a response to a wheel flat impact The ringing accelerations occur at 0.1 second intervals which

- RUN 400/8
- 55 MPH
- COUNTERCLOCKWISE
- EFFECTIVE SIGNAL BANDWIDTH - 800 Hz

FIGURE E-13 PIEZO ACCELEROMETER VERTICAL SIGNAL CHART RECORD

ds to a wavelength equal to the wheel circumference at the st speed.

ferences in peak values of the two redundant data signals er than 30 percent in some instances. Figure E-14 dis- quency spectra of the two signals. The plots agree within oughout the 2000 Hz bandwidth.



- RUN 400/8
- 55 MPH
- COUNTERCLOCKWISE
- SIGNAL BANDWIDTH - 2000 Hz

FIGURE E-14. PIEZO ACCELEROMETER REDUNDANT SIGNAL FREQUENCY SPECTRA

APPENDIX F

MISCELLANEOUS TESTS

The following test sets are described in this Appendix.

Test Category	Test Set No.	Test Title	Page
Miscellaneous	R42-I-0101-TT	Zero Signal Shift vs Cable Position	F-3
	R42-I-2106-TT	Carbody Voltage Variation	F-7
	R42-I-5105-TT	Magnetic Fixture Evaluation	F-12
	R42-I-0102-TT	Thermal Environment Three Bay Rack	F-16
	R42-I-5104-TT	Vehicle Shakedown Run	F-18

In addition, miscellaneous equipment observations conclude this appendix. They include:

1. Magnetic Tape Recorder Performance Summary.

2. Effect of Nearby Radio Transmission.

3. Vibration Isolation Characteristics of the Three-Bay Equipment Rack.

4. Power System Effect on Equipment Calibration.

TEST SET	TEST TITLE: Zero Signal Shift vs Cable Position TEST SET NO.: R42-I-0101-TT

TEST OBJECTIVE: To determine the zero signal shift of the signal conditioning amplifiers as a function of cable position.

TEST DESCRIPTION: The phenomenon creating zero shifts with cable position is believed to be rectification of RF within the amplifier integrated circuits. The effects may be significant at amplitude gains greater than 100X. Shifts of nearly ±1 percent full scale were produced in TSC laboratories. The effects at TTC were determined. The test was done while vehicle was on the test track.

STATUS: Sufficient data was collected to conclude that this effect may be neglected at TTC. All normal cable positions were simulated with zero shifts less than 0.02 percent FS.

FIGURE F-1. ZERO SIGNAL SHIFT VS CABLE POSITION TEST SUMMARY

F1. ZERO SIGNAL SHIFT VS CABLE POSITION

F1.1 TEST SUMMARY

Refer to figure F-1 preceding.

F1.2 PROCEDURE

During the TSC laboratory evaluation of the GVTS, it was observed that at amplifier gains exceeding 100X, the zero signal shifted as a function of cable position. The shift was as much as 1 percent FS output with the cable in certain orientations. In laboratories located on the outside walls of a building, the effect was especially noticeable. No shift occurred when the equipment was setup in a metallic screen room.

The phenomenon creating the zero shift is believed to be rectification of radio frequency (RF) radiation. With the input cable acting as an antenna, its position would vary the received RF and therefore the zero shift. Various types of RF filters were tested at TSC with no improvement achieved. It was determined that further work on this problem would be curtailed pending an evaluation at the primary test site, TTC.

At TTC, the transit vehicle was located at station 40 just north of the north transit switch. The third rail was not powered. The test cable was placed in coiled and extended configurations both inside and outside of the vehicle. All possible orientations were simulated.

F1.3 INSTRUMENTATION

A block diagram of the test equipment is shown in Figure F-2. Measurements were made on the digital voltmeter housed in

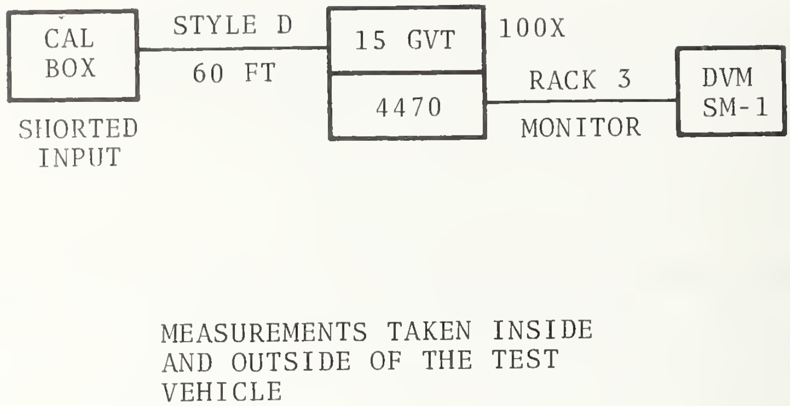


FIGURE F-2. ZERO SIGNAL SHIFT VS CABLE POSITION TEST EQUIPMENT BLOCK DIAGRAM

the signal monitor chassis. The amplifier utilized for this test was the TSC designed GVT mode card, TSC Model 4479.3S. The gain was 100X with the input shorted at the sensor end of a 60-foot long Style D, GVT cable.

F1.4 PROCEDURES

PRELIMINARY

A. Install test equipment as shown in Figure F-2.

B. Verify calibration by connecting a precision voltage source to input cable.

C. Complete log documentation sheets.

TEST

A. Place test cable in all possible simulated test positions.

B. Document zero shifts as a function of cable position.

F1.5 PRELIMINARY DATA ANALYSIS

The maximum zero signal shift throughout this test was ± 1 millivolt or 0.02 percent FS. No direct correlation with cable position could be determined. From this test, it is determined that the zero shift phenomenon does not occur at the TTC test site. The exact nature of the shift remains unexplained.

TEST SET	TEST TITLE: Carbody Voltage Variations TEST SET NO.: R42-I-2106-TT

TEST OBJECTIVE: To determine the potential difference between points on the carbody during vehicle acceleration and assess the effect of these differences on the measurement system.

TEST DESCRIPTION: Test probes of a floating differential voltmeter were manually positioned on the vehicle. Readings were taken during vehicle acceleration (maximum current draw).

All readings were documented in log.

STATUS: The test runs were performed and dc voltages up to 30 millivolts were measured on the carbody. Voltages of this magnitude should have a negligible effect on the measurement system.

FIGURE F-3. CARBODY VOLTAGE VARIATIONS TEST SUMMARY

F2. CARBODY VOLTAGE VARIATION

F2.1 TEST SUMMARY

Refer to Figure F-3 preceding.

F2.2 PROCEDURE

The carbody of the R42 vehicle is used as a current carrying conductor. A simplified block diagram of the current flow is given in Figure F-4. The control unit is mounted on glass insulators and all current flows through a single cable attached to the carbody. Starting currents up to 750 amps are typical on the R42 vehicle.

The stanchion attach points were used as voltage test locations. Figure F-5 schematically depicts these locations and the control unit ground connection to the carbody.

F2.3 INSTRUMENTATION

The only equipment used for this test was the digital voltmeter housed in the signal monitor chassis. This unit featured a floating, differential input.

F2.4 PROCEDURES

A. Using hand-held probes of the differential floating-input digital voltmeter, measure the potential differences generated by the ground current flowing through the car body resistance.

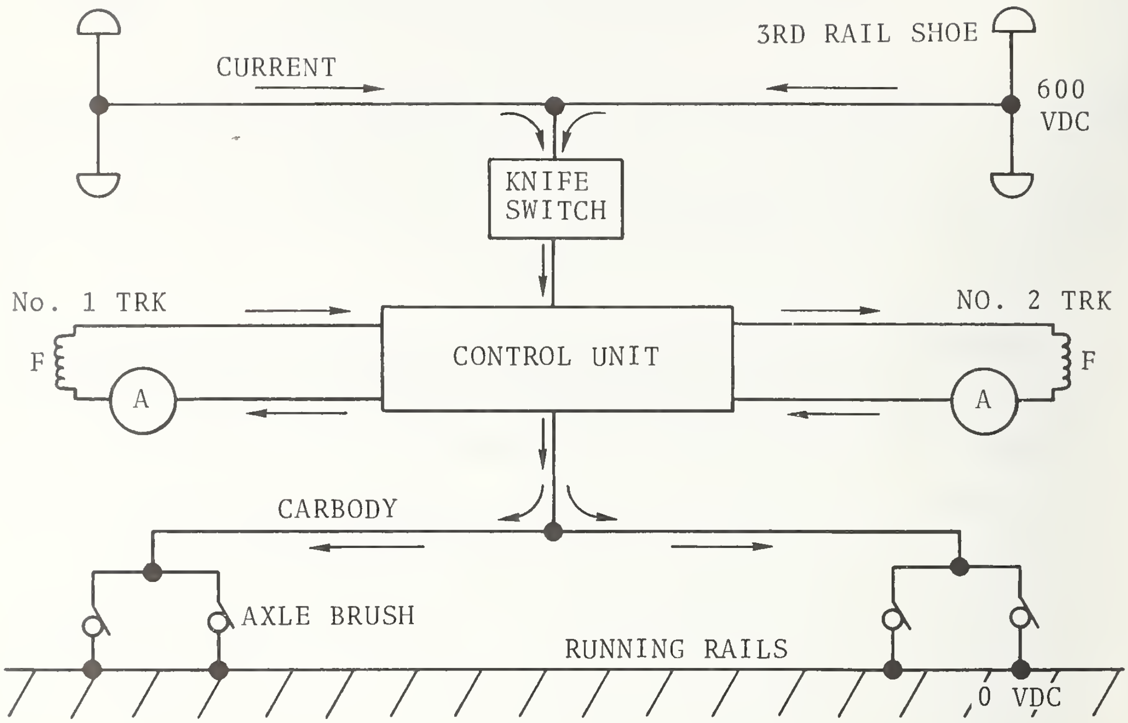


FIGURE F-4. SCHEMATIC OF R42 VEHICLE CURRENT FLOW

B. Record the maximum readings that occur during vehicle acceleration, when maximum current is being drawn, for all test points.

NOTES

1. THE EFFECT OF ANY GROUND POTENTIAL DIFFERENCE WILL BE CIRCULATING CURRENTS IN THE TRAIN GROUNDED CHASSIS (E. G., THREE-BAY RACK TO DAS VIA THIRD WIRE).

2. WHEN MEASURING LINE VOLTAGE, THE LO LEAD SHOULD BE RUNNING RAIL GROUND. IF SIGNIFICANT POTENTIALS (6 VOLTS = 1% OF 600) EXIST BETWEEN RUNNING RAIL GROUND AND SIG. LO, ERRORS WILL RESULT.

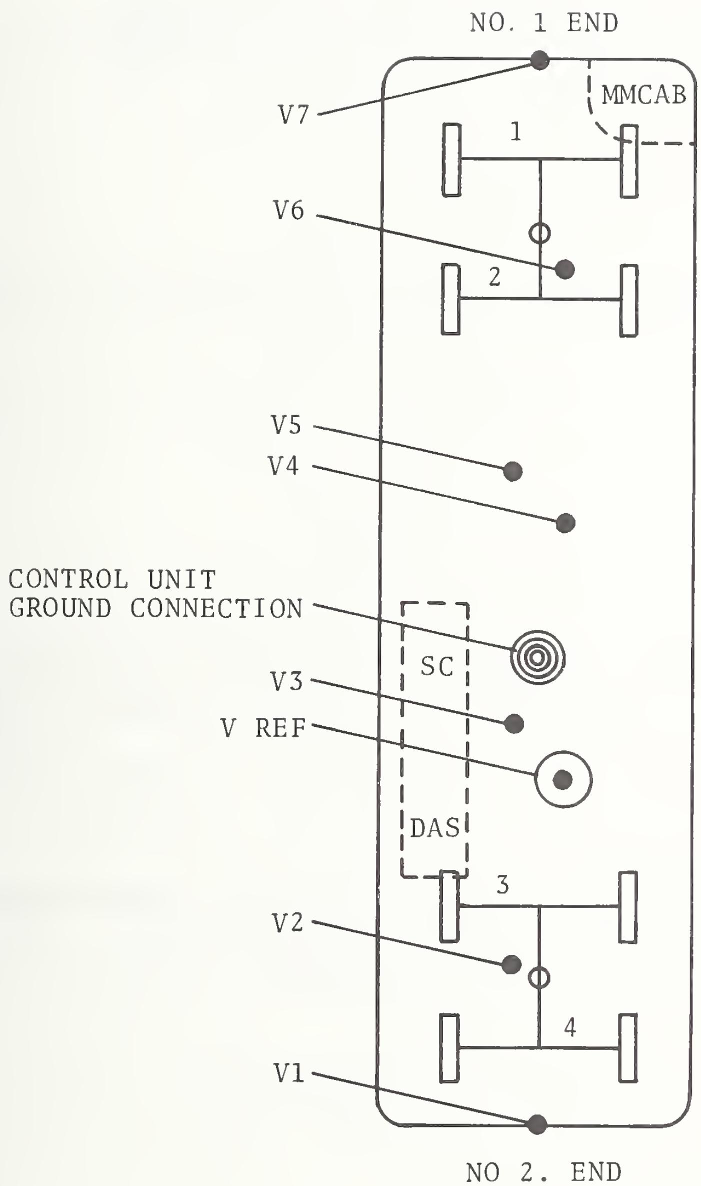


FIGURE F-5. SCHEMATIC OF CARBODY VOLTAGE TEST POINT LOCATIONS

F2.5 PRELIMINARY DATA ANALYSIS

The maximum potential difference during vehicle acceleration for each test point is given below. All voltages are given with respect to the V_{REF} test point.

V1	0.000 Volts
V2	0.001 Volts
V3	0.030 Volts
V4	0.021 Volts
V5	0.014 Volts
V6	0.009 Volts
V7	0.004 Volts

The maximum voltage reading occurred at V3 where the current density was highest. As the current flowed radially outward from the single point ground connection, the current density rapidly diminishes. As a result, the potential differences also diminish.

The 30 mV maximum dc voltage is not expected to create measurement difficulty with properly grounded systems.

TEST SET	
	TEST TITLE: Magnetic Fixture Evaluation TEST SET NO.: R42-I-5105-TT

TEST OBJECTIVE: To determine the effectiveness of using magnetic sensor fixtures and magnetic parameter labels for the signal conditioning system.

TEST DESCRIPTION: A machinist's type magnetic base was affixed to various metallic structures on the test vehicle. The vehicle was then operated under simulated GVT procedures and the movement of the fixture was noted.

Attachment points included:

1. Carbody Frame
2. Truck Frame
3. Stanchion
4. Equip. Rack

In addition, GVT parameter labels with magnetic backing were procured to aid real time monitoring of analog signals. Technique will be qualitatively evaluated.

STATUS: The evaluations were performed during the test series. Magnetic sensor fixtures did not adequately adhere to various vehicle structures. Their use is not recommended without detailed analysis.

The magnetic parameter labels did adhere satisfactorily and their use greatly facilitated the real-time monitoring of data signals. Use of the labels on the chart recorder is also recommended.

FIGURE F-6. MAGNETIC FIXTURE EVALUATION TEST SUMMARY

F3. MAGNETIC FIXTURE EVALUATION

F3.1 TEST SUMMARY

Refer to Figure F-6 preceding.

F3.2 PROCEDURE

The magnetic fixture evaluation test procedure number was R42-I-5105-TT. Any reduction in test set-up time is economically attractive. The use of magnetic sensor fixtures has the potential of eliminating time consuming custom fixture design and fabrication and/or adhesive mounting of sensors. A standard machinists type magnetic base was selected for evaluation.

Previous experience indicated that the real-time monitoring of up to 30 data channels could be troublesome. Referring to a master list of the constantly changing GVT parameters was deemed unacceptable. An easily changed individual label for each channel was devised. The label used the parameter abbreviations corresponding to the GVTP standard outputs. Attachment of the laminated plastic labels to the signal conditioning modules was achieved with a magnetic backing. Figure F-7 shows a label and its attachment to the module.

During the conduct of other tests during the series, the magnetic sensor fixture was mounted on available ferrous surfaces. In addition, the GVT labels were used throughout the series. The performance of each system was noted.

FIGURE F-7. GENERAL VEHICLE TEST MAGNETIC PARAMETER LABEL INSTALLATION

F3.3 INSTRUMENTATION

The magnetic base was manufactured by Starrett, Inc., Model No. 657.

F3.4 PROCEDURES

The procedures for this test were informal with the magnetic techniques qualitatively evaluated by the test crew.

F3.5 PRELIMINARY DATA ANALYSIS

Magnetic Sensor Fixtures

Performance of the magnetic sensor fixture was unsatisfactory. Adherence problems occurred because of surface roughness, finish (paint), and curvature. Static installations were sometimes

successful but fixture movement occurred during dynamic tests. While the use of custom designed magnetic fixtures is not precluded, design of a general purpose unit is not recommended.

GVT Magnetic Labels

During the two weeks of testing and forty-two test runs, two of the labels were inadvertently dislodged by members of the test crew. Future GVT tests with a more permanent test setup and additional operator experience should allow the labels to be used with little difficulty. Real time monitoring of the data signals was greatly facilitated by the channel labels. In addition, their pre-test installation provides a final check on the test configuration.

TEST SET	TEST TITLE: Thermal Environment Three Bay Rack TEST SET NO.: R42-I-0102-TT

TEST OBJECTIVE: To determine the thermal environment of the three bay equipment rack and correct any deficiencies. Minimize rack/ambient differential temperatures and eliminate hot spots.

TEST DESCRIPTION: With all equipment warmed-up and operating in a simulated GVT mode, (sunlight, high ambient temp., etc.) a temperature probe was to be manually positioned at selected rack locations. All readings were to be documented in the log and corrective action taken.

STATUS: Due to test time constraints, this test was not performed. System performance on other tests in this series did not indicate any thermal problems. No other information on this test is included in this appendix.

FIGURE F-8. THERMAL ENVIRONMENT, THREE BAY RACK TEST SUMMARY

F4. THERMAL ENVIRONMENT THREE BAY RACK

F4.1 TEST SUMMARY

Refer to Figure F-8 preceding.

TEST SET	TEST TITLE: Vehicle Shakedown Run TEST SET NO.: R42-I-5101-TT

TEST OBJECTIVE: To verify safe installation of all equipment on test car.

TEST DESCRIPTION: After the installation of all test equipment and securing cabling, a complete test loop CW at widely varying speeds was performed. A visual observation of all equipment to verify a safe operating environment was made. At selected locations, the vehicle was stopped and undercar equipment was inspected. The complete test loop was traversed. All equipment was observed and verified to be in a safe operating condition.

STATUS: During the conditioning runs, the vehicle was stopped as required and all in-car and undercar equipment installations were inspected. No malfunctions of equipment mounting fixtures were observed during the test period.

FIGURE F-9. VEHICLE SHAKEDOWN RUN TEST SUMMARY

F5. VEHICLE SHAKEDOWN RUN

F5.1 TEST SUMMARY

Refer to Figure F-9 preceding.

F6. MISCELLANEOUS EQUIPMENT OBSERVATIONS

F6.1 MAGNETIC TAPE RECORDER PERFORMANCE SUMMARY

The tape calibration signals were reproduced on tracks 4 through 14 before and after four-30-minute test runs. The maximum zero drift was -0.5 percent FS with typical values between ± 0.2 percent FS. The maximum gain shift was +0.4 percent with typical values between ± 0.2 percent FS. Frequency spectra of tape noise were generated at 1 7/8 and 15 ips for an odd and even channel. The even chanel noise components were less than two millivolts peak in all cases. The odd channel noise components were less than one millivolt peak.

At the beginning of the test series, in order to maximize floor space, the recorder was mounted to the equipment rack with the plane of the tape reels vertical. Excessive noise was evident on reproduced channels with occasional drop out. The unit was remounted using the vibration mount specifically designed for this recorder. The planes of the reels were horizontal in the second installation. A significant reduction in noise level resulted.

To further reduce the noise, a zero signal was recorded on channel one. During data playback, this zero signal was differentially summed with all other channels to compensate for any tape speed variations.

F6.2 EFFECT OF NEARBY RADIO TRANSMISSION

Test center communications are accomplished with hand held walkie-talkies assigned to key personnel. These units operate at approximately 170 megahertz with a power of five watts. Occasionally during the conduct of a test, the keying of an on board walkie-talkie created a zero shift on data channels utilizing high gain.

A brief test indicated that shifts exceeding the full scale range occurred on a strain gage system (gain 1000X) when the walkie-talkie was within a few feet of the equipment rack. With the unit located at the opposite end of the vehicle, the effects were reduced by approximately 90 percent. When transmissions were made from the other test vehicle the effects were again reduced. No attempt is made to quantify the error as different shifts occurred on seemingly identical channels. It is recommended that radio transmissions during a test run be kept to the absolute minimum. Any extended communications should be documented in the test log.

F6.3 VIBRATION ISOLATION CHARACTERISTICS OF THE THREE-BAY EQUIPMENT RACK

During the accelerometer tests, the sensors were also mounted to furnish data to evaluate the vibration mount of the three bay equipment rack. Both vertical and lateral accelerometers were mounted on the car floor and equipment rack. The locations are shown in Figure E-2.

Seven constant speed test runs were made between stations 330 and 310. Speeds ranged from 15 MPH to 55 MPH. Figure F-10 is a chart recording of the accelerometer data from Run 400/8 at approximately 55 MPH. Frequency spectra of the rack and floor accelerometer data are shown in Figure F-11. From the spectra, the following natural frequencies (f_N) and transmissability ratios (TR) were determined:

	f_n	TR
Vertical	14 Hz	3
Lateral	18 Hz	5

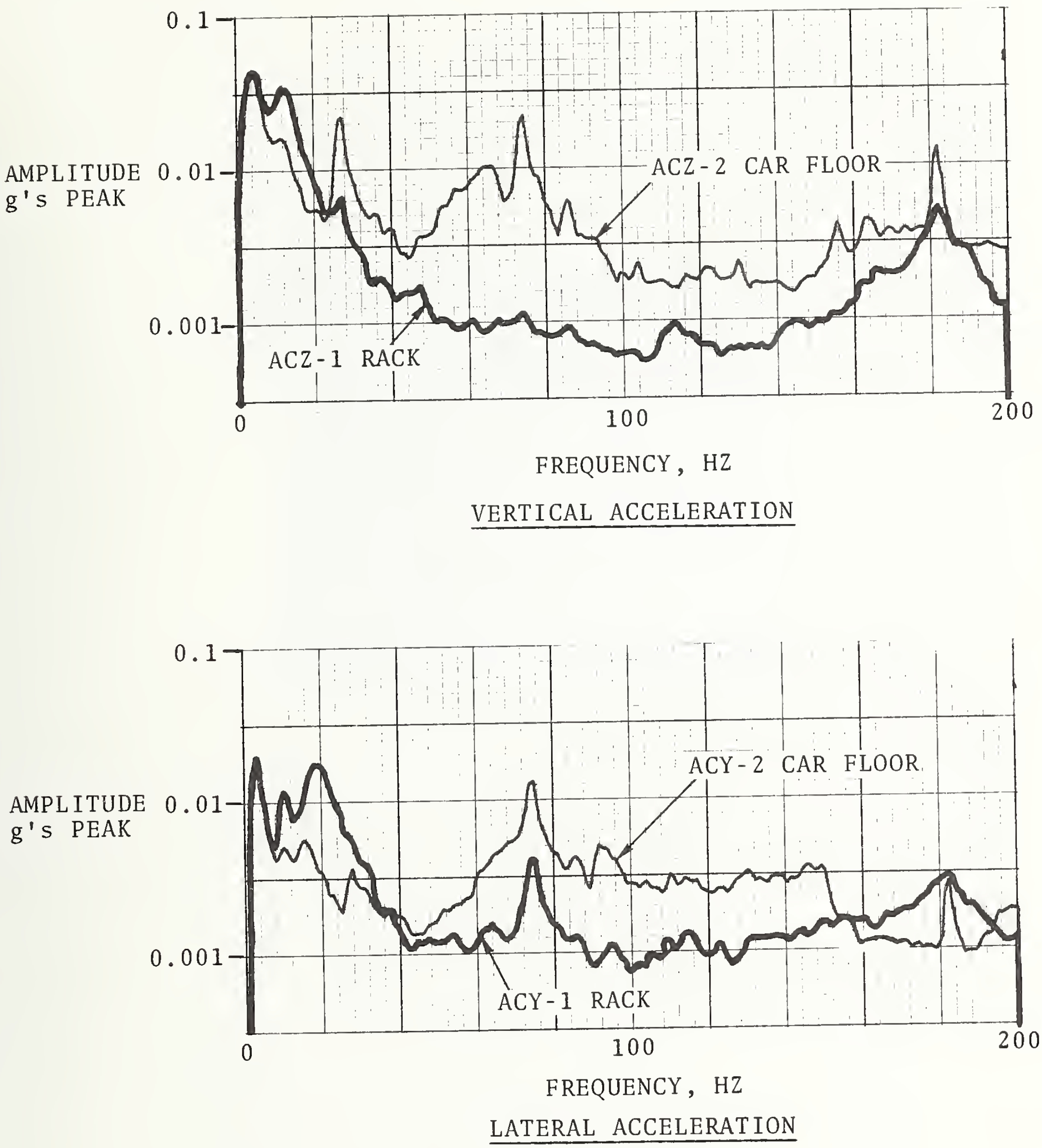
These values are approximately one octave above the estimated vehicle suspension system resonant frequencies, and one octave below the body bending mode frequencies. It is noted that the TR at frequencies above 160 Hz approaches unity. This is caused by the friction damping mechanism within the shock mount not experiencing sufficient displacement to effect damping.

F6.4 POWER SYSTEM EFFECT ON EQUIPMENT CALIBRATION

Power for the test instrumentation was furnished by two sources, a diesel generator, and a solid state 600 vdc to 115 ac inverter. A tape calibration was performed prior to run 300/3 with power provided by the generator, and the calibration repeated with power provided by the inverter. Post test data processing indicated no difference in the zero signal level and gain for both calibrations.

- RUN 400/8
- 55 MPH
- COUNTERCLOCKWISE
- EFFECTIVE SIGNAL BANDWIDTH - 320 Hz

FIGURE F-10. THREE-BAY RACK VERSUS CAR FLOOR ACCELERATION SIGNAL CHART RECORD



- RUN 400/8
- 55 MPH
- COUNTERCLOCKWISE
- 200Hz RANGE

FIGURE F-11. THREE-BAY RACK VERSUS CAR FLOOR ACCELERATION SIGNAL FREQUENCY SPECTRA

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U. S. DEPARTMENT OF TRANSPORTATION
TRANSPORTATION SYSTEMS CENTER
KENDALL SQUARE, CAMBRIDGE, MA. 02142